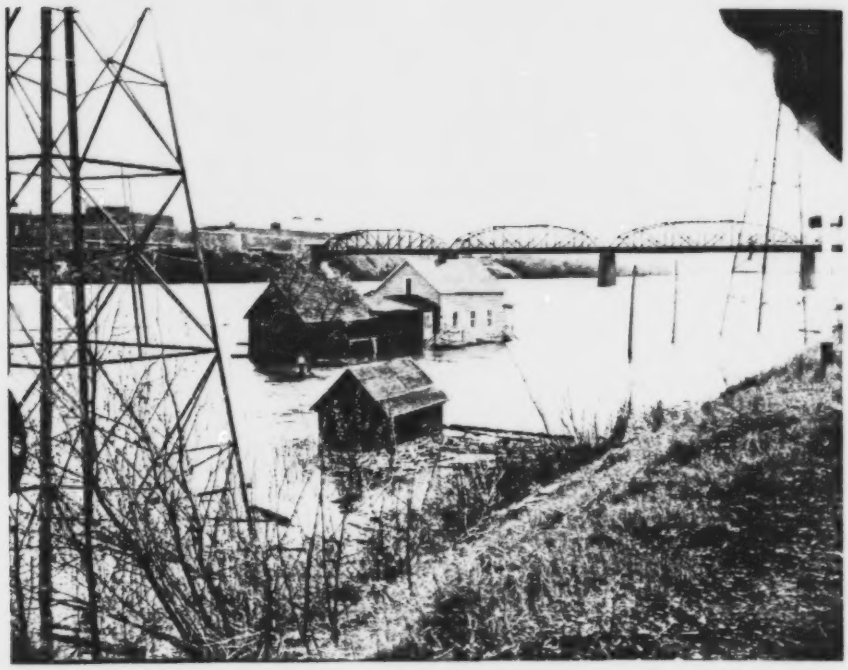
FINAL REPORT

DOCUMENTATION AND ASSESSMENT FLOOD DAMAGE POTENTIAL SAINT JOHN RIVER SAINT LEONARD TO CLAIR



CANADA - NEW BRUNSWICK FLOOD DAMAGE REDUCTION PROGRAM

NOLAN,DAVIS & ASSOCIATES (N.B.) LIMITED

July,1991

DOCUMENTATION AND ASSESSMENT

FLOOD DAMAGE POTENTIAL - SAINT JOHN RIVER

CLAIR TO SAINT LEONARD

PREPARED FOR:

CANADA-NEW BRUNSWICK

FLOOD DAMAGE REDUCTION PROGRAM

By:

Nolan, Davis & Associates (N.B.) Limited

In Association With

Cumming Cockburn Ltd.

Key Surveys Ltd.

July, 1991

NOLAN, DAVIS & ASSOCIATES (NB) LIMITED
ENGINEERS AND SCIENTISTS

403 Regent Street, Suite 6
Fredericton, New Brunswick E3B 3X6
Telephone: (506) 458-9770
Fax: (506) 450-2933

July 24,1991
File No. F90-042

Water Resource Monitoring
Environmental Planning and Sciences Branch
New Brunswick Department of the Environment
P.O.Box 6000
Fredericton,N.B.
E3B 5H1

Attention: Program Manager
Mr. J.G. Lockhart
Canada-New Brunswick
Flood Damage Reduction Program

Documentation and Assessment
Flood Damage Potential
Saint John River
Clair to Saint Leonard

Dear Sirs:

We are pleased to submit 30 copies of our final report for the above noted project. The comments of the Mapping and Studies Committee concerning the draft version have been incorporated in the final report as agreed. We have also included the flood profile of the 1991 event for this report. The results of the field work carried out during the course of this study have been presented in a separate report entitled " Supplementary Report on Field Investigations."

We would like to express our appreciation to the members of the Mapping and Studies Committee for their cooperation and assistance during the study. If you have any questions concerning the content of this report please contact us.

Yours very truly,
NOLAN, DAVIS & ASSOCIATES
(N.B.) LIMITED

M.D.Riley, P.Eng.
President

92-01926/

Executive Summary

In September, 1990 Nolan Davis and Associates (N.B.) Limited in association with Cumming Cockburn Limited and Key Surveys was retained by the New Brunswick Department of the Environment under the Canada-New Brunswick Flood Damage Reduction Program to carry out the documentation and assessment of flooding along the Saint John River in Northwestern New Brunswick from Saint Leonard to Clair. The principal objective of the Study was to determine the maximum extent of past historical floods in the Study Area which extends from Saint Leonard to Claire and encompass Saint Leonard, Grand River, Saint-Anne-de Madawaska, Quisbis, Rivieré Verte, Edmundston, Saint Hilaire, Baker Brook, Caron Brook and Clair.

The documentation of previous flooding events involved the collection and assessment of all historical data through archival research, and contacts with public and private organizations, local authorities and residents. In the 106 years since 1885 a total of 27 flood events, corresponding to a frequency of one flood event every 3.9 years has been recorded. A total of 122 historic references to previous flooding events, including 17 for the recent 1991 event were identified and documented.

A total of 67 high water marks were located in the field. Of these points, 33 were based on photographs, 29 were field identified high water marks or ice scars, and 5 points were identified from the Water Survey of Canada or United States Geological Society historical records. The high water marks and ice scars were surveyed to Geodetic Survey of Canada datum.

The 20 and 100 year water flood elevations were developed over the Study Area using a calibrated HEC-2 hydraulic computer model provided by N.B. Power. The model, using peak instantaneous flows developed from Regional Regression equations, provided reasonable results for the purpose of this study. The Perception Method was utilized to determine the probability distribution of flood levels from historical observations.

A comparison of the result of both analysis showed the historical flood data from the Perception Method to be fairly consistent with open water flood levels obtained from HEC-2 modelling. The results of this study indicate that historical events are of a considerably lower return period that the 100 year flow modelled.

Remedial measures for the Study Area include raising the Trans Canada Highway at Saint Anne de Madawaska, and raising the berms of the sewage treatment lagoon at Saint Basile. A protective flood wall, constructed in the 1970s at Fort Kent, appears to be providing adequate protection for this area.

Résumé Administratif

En septembre 1990, le ministère de l'Environnement, en vertu du Programme Canada-Nouveau-Brunswick sur la réduction des dommages causes par les inondations, a retenu les services de Nolan Davis and Associates (N.B.) Limited, de Cumming Cockburn Limited et de Key Surveys pour effectuer une étude des zones inondables dans le long de la rivière Saint Jean du nord-ouest nouveau brunswick. L'étude avait principalement pour but de déterminer l'ampleur des inondations survenues au cours des années dans la zone visée que Saint Leonard a Claire comprendre Saint Leonard, Grand River, Saint-Anne-de Madawaska, Quisbis, Rivieré Verte, Edmundston, Saint Hilaire, Baker Brook, Caron Brook et Clair.

Pour établir une documentation sur les inondations survenues par le passe, il a fallu faire la collecte et l'évaluation de toutes les données historiques a l'aide de recherches dans les archives, communiquer avec des organismes publics et prives ainsi qu'avec les autorités locales et les résidents. Dans 106 ans, c'est-à-dire depuis 1885, on a enregistre au total 27 inondations, ce qui correspond a une inondation tous les 3,9 année. Un total de 122 références historiques aux inondations comprendre 17 survenues par le passe ont été identifiées et documentées.

Un total de 67 laisses des hautes eaux ont été localisées sur place. De ces laisses des hautes eaux, 33 étaient basées sur des photographies, 29 étaient des laisses de hautes eaux identifiées sur place, et étaient identifie a partir des dossiers de la Division des relevés hydrographiques du Canada ou États Unis Géologique Société. On a aussi identifie et étudié 16 cicatrices glaciales. Les laisses des hautes eaux et les cicatrices glaciales ont été étudiées pour les donnés de la Division des relevés géodésiques du Canada.

Les niveaux de crue de tous les 20 et de tous les 100 ans ont été établis dans chaque localité de la zone visée a l'aide du modèle informatique hydraulique HEC-2 contribué a NBPower. Il a été présumé que le modèle utilisant des débits de pointe instantanés établis a partir d'équations de régression régionale fournissait des résultats raisonnables aux fins de la présente étude. La méthode Perception a été utilisée pour déterminer la probabilité de la répartition des niveau d'inondation a partir des observations historiques.

Une comparaison des résultats des deux analyses indique que les donnés historiques sur les inondations obtenues a l'aide de la méthode Perception sont relativement constantes par rapport aux niveaux d'inondation des eaux libres obtenus par le modèle HEC-2. Les résultats de cette étude révèlent que les événements historiques ont une période de récurrence grandement inférieure au débit modélisé de 100 ans.

Les mesures de redressement pour la zone visée par L'étude ériger Trans Canada Highway a Saint Anne de Madawaska, and ériger le berms de la lagune. L'étude pour ériger la route Transcanadienne a Saint Anne de Madawaska, et ériger les berms de la lagune égout traitement a St. Basile. La mur inondation pour protéger était construite dans les ânes 1970 a Fort Kent, semble a protéger suffisante la région.

TABLE OF CONTENTS

Page

Letter of Transmittal i

Executive Summary ii

Résumé Administratif iii

Table of Contents iv

List of Tables vi

List of Figures vii

1.0 Introduction 1

1.1 General 1
1.2 Objectives and Scope of Work 2

2.0 Study Area 3

2.1 Boundaries 3
2.2 Geographical Features and Physiography 5

3.0 Flood Documentation 6

3.1 Introduction 6
3.2 Collection and Assessment of Historical Data 6

3.2.1 Existing Information 6
3.2.2 Archival Research 7
3.2.3 Public and Private Agencies 8
3.2.4 Local Authorities and Residents, Interviews and Questionnaires 8
3.2.5 Flood of 1991 9

4.0 Data Compilation 10

4.1 Flooding History 10
4.2 Preliminary Evaluation of Data 13
4.3 Field Reconnaissance and Survey 14

5.0 Hydrology 16

6.0 Envelope of Maximum Flooding 18

6.1 Perception Method 18
6.2 Open Water Flood Limits 19
6.3 Identification of Remedial Measures 27

7.0 Discussion 29

8.0 References 31

Appendices

Appendix I Historic Flood Documentation ..... 7 pages

Appendix II Hydrology ..... 11 pages

Appendix III Perception Method ..... 10 pages

LIST OF TABLES

		Page
Table 2-1	Control Sections - Study Area	3
Table 4-1	Summary of Previous Flooding Events - Upper Saint John River	11
Table 4-2	Identified Flood Events/Community	13
Table 4-3	Ranking of Reference Points	14
Table 4-4	Summary of Field Survey	15
Table 5-1	Summary of Flood Flows	17
Table 6-1	Historic and Open Water Flood Elevations	20
Table I-1	Historic Flood Documentation	I-2
Table II-1	Regional Regression Equations	I-2
Table II-2	Regional QP/QD Regression Equation	II-5
Table II-3	Frequency Analysis - Three Parameter Lognormal Distribution - Saint John River at Fort Kent	II-8
Table II-4	Frequency Analysis - These Parameter Lognormal Distribution - Saint John River at Edmundston	II-9
Table II-5	Frequency Analysis - Three Parameter Lognormal Distribution - Saint John River at Grand Falls	II-10
Table II-6	Summary of Flood Flows	II-11
Table III-1	Summary of Computed and Historical Flood Elevations	III-3

LIST OF FIGURES

		Page
Figure 2-1	Site Plan Study Area	4
Figure 6-1	Saint John River - Saint Leonard to Saint Anne de Madawaska 0-17.0 km	22
Figure 6-2	Saint John River Saint Anne de Madawaska - Saint Basile 17.0-34.0 km	23
Figure 6-3	Saint John River - Saint Basile to Saint Hilaire 34.0 - 51.0 km	24
Figure 6-4	Saint John River-Saint Hilaire to Baker Brook 51.0 - 68.0 km	25
Figure 6-5	Saint John River-Baker Brook to Clair - 68.0 - 84.0 km	26
Figure II-1	Perception Method - Saint Leonard/Van Buren	III-4
Figure III-2	Perception Method - Saint Anne de Madawaska and Quisbis	III-5
Figure III-3	Perception Method - Green River	III-6
Figure III-4	Perception Method - Edmundston	III-7
Figure III-5	Perception Method - St. Hilaire	III-8
Figure III-6	Perception Method - Baker Brook	III-9
Figure III-7	Perception Method - Clair/Fort Kent	III-10

1.0 INTRODUCTION

1.1 GENERAL

Flooding is a natural process. Man however, has historically been attracted to floodplains primarily because of their fertile soils and their proximity to water based transportation. As communities grow, they attract more development (including land-based transportation systems) some of which is usually located on flood plain lands. In some cases this development further compounds the flooding problem by reducing the natural water conveyance capacity of rivers and thus increases the height and extent of flood waters. (1) The impact of flooding on populated areas can be very serious resulting in both loss of life and property. The resulting loss to property from flooding can be in the millions of dollars.

In recognizing the potential for flood damage and the potential for reduction through control of the uses of areas prone to flood damage, the Province of New Brunswick and Government of Canada have entered into a "General Agreement Respecting Flood Damage Reduction." The objective of this agreement is the reduction of potential flood damage on floodplains along the shores of lakes, rivers and the sea.

Initially flood damage reduction studies to identify and delineate such flood prone areas were carried out under agreements which terminated in 1986. A combined Mapping and Studies Agreement, signed March 31, 1988 has replaced the initial agreements. Under the terms of the current agreement, a number of flood prone areas in the Province are to be mapped and the flood risk zones delineated ultimately as areas wherein only certain approved development can take place. The current agreement also provides for the assessment of structural and non-structural remediation works where warranted.

Under the Mapping and Studies Agreement, Nolan, Davis & Associates (N.B.) Limited, in association with Cumming Cockburn Limited and Key Surveys Inc. was retained by the New Brunswick Department of the Environment to carry out the documentation and assessment of flooding along the Saint John River in Northwestern New Brunswick from Saint Leonard to Clair. This report presents the results of this study.

1.2 OBJECTIVES AND SCOPE OF WORK

The principal objective of this study was to determine the maximum extent of flooding within the Study Area. The scope of work to meet this objective includes the :

i) documentation of the occurrence and magnitude of past floods in the Study Area,

ii) determination of the historical flood profile at the designated communities,

iii) determination of the approximate 100 year flood profile for comparison to the historical flood profile,

iv) identification of possible remedial work to reduce flood damages in each community.

This study examined the frequency, nature and extent of flooding within the flood-prone areas of the Saint John River Basin from Saint Leonard to Clair, N.B.

2.0 STUDY AREA

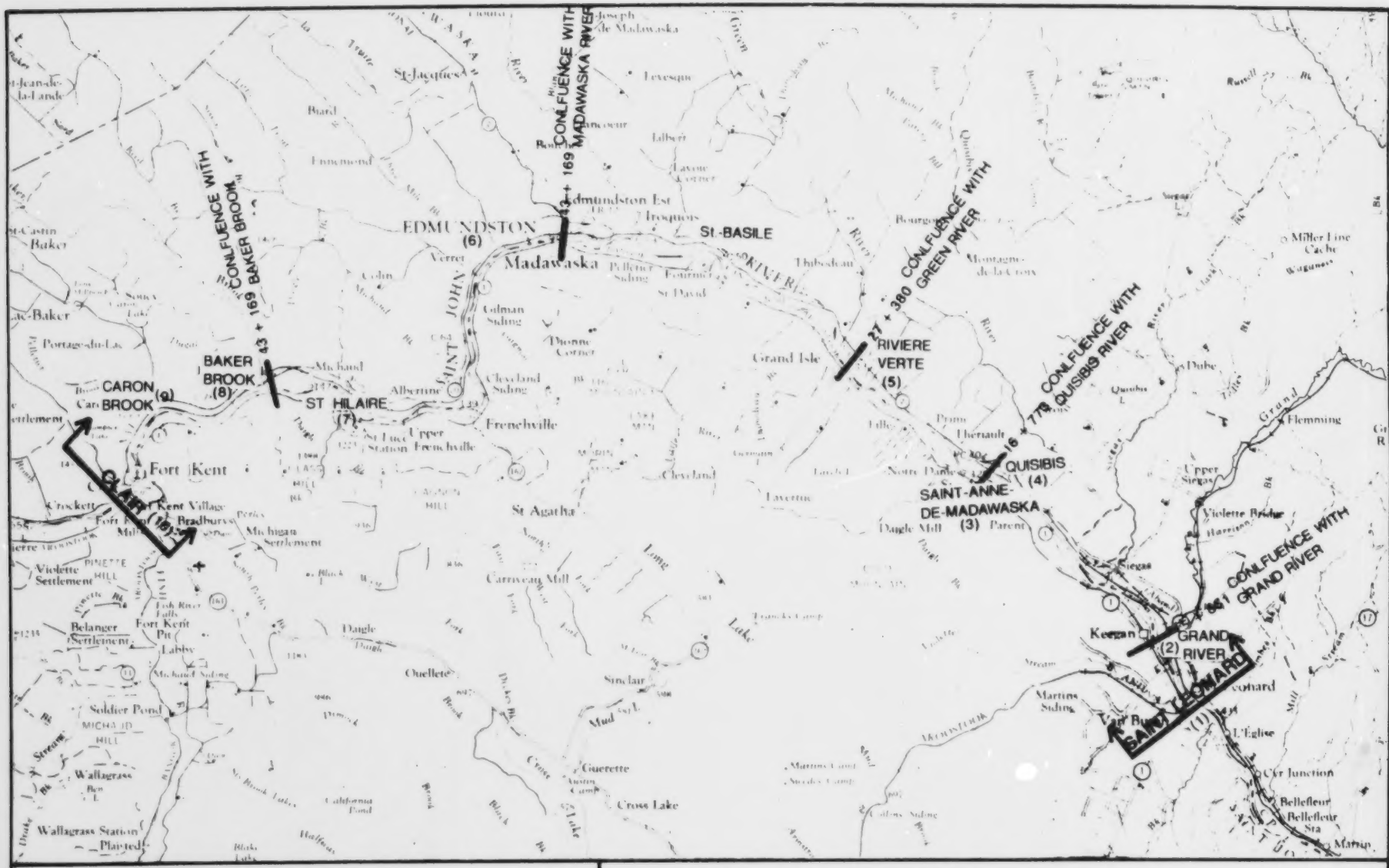
The Study Area encompasses the area prone to flooding along the Saint John River, between the communities of Saint Leonard [1] and Clair [10] and includes the communities of Grand River [2], Saint-Anne-de Madawaska [3], Quisbis [4], Rivieré Verte [5], Edmundston [6], Saint Hilaire [7], Baker Brook [8] and Caron Brook [9]. The number appearing in the square brackets after each of the communities refers to the designated identification number which has been assigned to each community for the Study. The approximate limits of the Study Area are shown in Figure 2-1.

The Study Area starts two kilometres downstream of the International Bridge at Saint Leonard/Van Buren and extends to approximately three kilometres upstream of the Internal Bridge at Claire/Fort Kent. The Saint John River measured along its stream bed extends approximately 84 kilometres over the Study Area. Table 2-1 summarizes the chainage at a number of control points over the Study Area.

Table 2-1

Control Sections - Study Area

Control Station	Chainage (m)
International Bridge - Saint Leonard	2 + 000
Confluence with Grand River	5 + 861
Confluence with Quisbis River	16 + 773
Confluence with Green River	27 + 380
Confluence with Madawaska River	43 + 169
International Bridge - Edmundston	43 + 930
Confluence with Baker Brook	67 + 132
Water Level Gauge at Fort Kent	78 + 760
International Bridge - Clair	80 + 074



NOLAN, DAVIS & ASSOCIATES

SAINT JOHN RIVER FLOOD STUDY
SAINT LEONARD to CLAIR
SITE PLAN

SCALE 1 : 250 000

FIGURE 2-1

2.2 GEOGRAPHICAL FEATURES AND PHYSIOGRAPHY

The Saint John River measured along its stream bed is approximately 700 km long from its point of origin above Little Saint John Lake in Maine to its confluence with the Bay of Fundy in Saint John, N.B. The total drainage area is 55 200 sq km of which 51% lies in New Brunswick, 13% in Quebec and the remaining 36% in the State of Maine.

The Saint John River, in its path towards the sea, flows through several distinct geographical areas having its origins in the Chaleur Uplands, flowing through the New Brunswick Highlands and Lowlands until it reaches the Caledonia Highlands (2). The Study Area is located entirely within the Chaleur Uplands.

The Saint John River is fed by a number of short tributaries. Two important rivers which connect with the Saint John within the Study Area are the Madawaska River and Green River. Other smaller tributaries include Baker Brook, Quisbis River and Grand River.

The Chaleur Uplands, which comprise most of the River Basin above Woodstock, are characterized by swampy plains and numerous lakes. The regularity of the Upland plan is broken by valleys such as the Saint John River and by ridges and peaks. Generally, the Chaleur Highlands are underlain by Lower Palaeozoic sedimentary rocks consisting chiefly of shale, argillite, sandstone and limestone. Most of the land in the Chaleur Uplands is forested.

The preglacial valley of the Saint John River, which was much wider and deeper than its present valley, was infilled with overburden in the Pleistone Age. Although the Saint John River still flows in the same valley, it has only partially eroded the glacial deposits and has not cut down to its preglacial level. The overburden, consisting mainly of cobbles and boulders, was deposited in a blanket of varying thickness over the bedrock. The cover is generally thin over hills and deeper in the valleys. It is absent on the tops and steep slopes of some hills. The composition of the till generally reflects the characterization of the underlying bedrock (2). Over the Study Area, the till is generally silty reflecting the underlying shale bedrock.

3.0 FLOOD DOCUMENTATION

3.1 INTRODUCTION

The annual peak runoff in the Saint John River Basin usually occurs in either April or May with about equal probability, and occasionally in March or June. The peak runoff is usually the result of precipitation in conjunction with snowmelt, but either factor may predominate. Fall storms occasionally produce flood peaks from August to December but these are seldom of the same magnitude as the spring floods.

Climatic conditions in the upper part of the Saint John River Basin favour the accumulation of heavy snowpacks by the end of winter season. Thus most of the winter snowfall, except that lost by evaporation, is available for runoff once the melting season begins. The maximized snow pack available coupled with spring storms can create maximum flood conditions.

Ice jams are frequently a complicating factor in a flood situation. Flood damages may sometimes be caused by the backwater from these jams rather than by excessive stream discharges. Structural damage to hydraulic structures such as bridges and culverts is generally higher during ice jams events, than during flooding events that do not involve ice movement and/or ice jamming. While ice jams have occurred in the Study Area, its effect has not been as catastrophic as in other areas of the Province such as Perth-Andover. In the upper reaches of the Saint John River, flood damage usually consist of bank erosion, loss of agricultural soil and the disruption of transportation systems.

3.2 COLLECTION AND ASSESSMENT OF HISTORICAL DATA

The flood documentation aspect of the study involved the collection and assessment of all historical flood data by contacts made with public and private organizations, local authorities, residents and archival research. All collected information was compiled and assessed as to its accuracy.

3.2.1 Existing Information

The initial task of the study was the collection and review of the available information on the flooding problem along the Saint John River between Saint Leonard and Clair. A listing of the reference material considered

relevant to the study is provided in Section 8.0. The purpose of the review of these references was to:

(i) obtain documentary evidence such as photographs, descriptions, etc. of past flood events (See Supplementary Field Report);

(ii) obtain the dates of historic flood events to assist in subsequent archival research.

A major source of information on previous flood events was the revised Kindervater Report "Flooding Events in New Brunswick An Historical Perspective" (1). This report provided a summary of flooding events in New Brunswick as recorded in newspapers and served as a starting point for this study.

The available 1:2000 or 1:2400 mapping of each of the communities in the Study Area was also assembled. The streambed chainage along the Saint John River was marked on this mapping for use in subsequent field surveys.

3.2.2 Archival Research

As part of the archival search, libraries, historical societies, professional photographers and local experts were solicited for additional information which might be useful for the Study. The archival records at Provincial Archives and the Harriet Irving Library of the University of New Brunswick were examined for information and photographs of past flooding events. An archival search was also carried out of the following newspapers.

The Telegraph Journal
The Daily Gleaner
The Madawaska
The Cataract - La Cataracte (1955-1982)
The Cataract Weekly / La Cataracte Hebdmadaire (1953-55)
The Cataract of Victoria County Weekly (1938-56)
Victoria Weekly
Victoria County Record

La Pointe Studios in Edmundston, which has been established since 1935 and has been supplying photographs to the provincial newspapers, was contacted. They were able to provide a number of excellent photographs for the Study (See Supplementary Field Report).

3.2.3 Public and Private Agencies

In the collection of historical data a number of both private and public agencies were resourced. These organizations included:

Environment Canada, Water Survey of Canada
New Brunswick Department of the Environment
Emergency Measures Organization
New Brunswick Electric Power Commission
Customs Canada
Town of Fort Kent
City of Edmundston
United States Geological Survey

In contacting these agencies discussions were held with key individuals who had some knowledge of past flooding events.

The Department of the Environment provided a significant amount of documentation in the form of photographs from previous flooding events. However, probably the single most significant source of relevant information was the New Brunswick Electric Power Commission (N.B. Power) who provided a large number of photographs of previous flooding events. Flood levels on many of these photographs were subsequently identified in the field. N.B. Power also made available to the Study a HEC- 2 computer model for the Study Area. This computer model, which is used by N.B. Power to analyze the flow regime of the River above the Grand Falls Generating Station, was invaluable in generating the 100 year flood profile for the Study Area (See Section 6.2).

3.2.4 Local Authorities and Residents, Interviews and Questionnaires

Historical information was also solicited from local residents and officials who had specific knowledge of previous flooding events. In September 1990, an invitation soliciting public support and information was printed in the Telegraph Journal. As well, through the Department of the

Environment, notices of the Study were sent to all mayors in the area. However, the request for public assistance through this avenue resulted in only one reply.

A number of people who were identified during the course of the study as possibly having relevant information were also contacted. Of these contacts, discussions with Mr. John Hughes of Grand Falls and Mr. Roy Gardner of Allagash proved to be most beneficial. Mr. Gardner has been retained as an observer by the Department of the Environment for the Saint John River for a number of years. Mr. Hughes was previously employed as a river observer for N.B. Power, Mr. Hughes experience on the Saint John River date back to the 1920's.

3.2.5 Flood of 1991

During the early April, 1991 heavy rains coupled with spring snowmelt resulted in high flows in the upper Saint John River with peak flow occurring on April 12, 1991. Ice jamming at Saint Basile and Edmundston resulted in heavy flooding of the area between Sainte-Anne-de-Madawaska and Baker Brook. At the request of the Department of the Environment, Nolan Davis field crew surveyed to geodetic datum a total of 10 high water marks from this event between Edmundston and Quisbis. In addition 7 high water marks from this event between Quisbis and Saint Anne-de-Madawaska were surveyed to geodetic datum by N.B. Department of the Environment.

4.0 DATA COMPILATION

4.1 FLOODING HISTORY

The data on historical flooding was used to compile a listing of the notable flooding events along the upper Saint John River between Saint Leonard and Clair since 1885. A summary of this information is given in Table 4-1 which provides in addition to dates, key comments which have been extracted from various sources.

In the 106 years since 1885 a total of 27 flood events of significance have been recorded in the Study Area. This corresponds to a frequency of one flood every 3.9 years. The most recent serious flooding occurred in 1979 at Caron Brook, Baker Brook, Edmundston, Rivieré-Verte, Sainte-Anne-de-Madawaska, Siegas, and Grand Falls, as a result of heavy precipitation and snowmelt. The highest recorded discharge at Grand Falls occurred in 1979. In 1969, similar conditions prevailed at Edmundston, Sainte-Anne-de-Madawaska, and Riviére-Verte. Edmundston has also experienced flooding in 1902, 1922, 1933, 1961 and 1974.

Generally, most notable floods were caused by spring freshets accompanied, in some instances, by ice jams. The ice jams tend to be localized and do not remain stationary for any significant period of time. Both John Hughes and Roy Gardner, two experienced river observers, have indicated to the Study Team that ice jamming has never been a major problem in the Saint John River between Grand Falls and Clair. Above Clair, which is outside the Study Area, ice jamming has been more of a factor in the flooding problem. In 1973, an ice jam at Cross Rock backed up jam ice to above the Dickey Bridge. This resulted in ice crossing a low spot in the road not too far below Dickey. The ice moved an unoccupied house off its foundation.

Two areas in the Study Area where flooding has caused significant problems are the Town of Fort Kent, Maine and at the mouth of the Grand River. At Fort Kent, the flooding used to cause problems in the downtown area. However, since flood control dykes were constructed along the river bank in the 1970s, there has not been any significant flooding of the downtown area. At the mouth of the Grand River, residences and a trailer park have been built in a low plain that routinely floods.

Table 4-1

SUMMARY OF DOCUMENTED FLOODING EVENTS
Upper Saint John River
Saint Leonard - Clair

Year	Date	Comments
1885	July	River rose 16 feet at Van Buren, Saint-Basile flats flooded.
1887	April 25-May 14	Mills damaged at Saint Leonard, Edmundston and Green River
1896	April 23-May 5	Water over road and rail road tracks at Green River. Ice jamming at Saint-Basile and Green River
1898		Victoria Street in Edmundston flooded
1902	March 17-23	Water in streets of Edmundston. Ice jam upstream of Edmundston
1912	August 8-12	River at Saint Leonard rose 8 ft.
1922	June 17-25	Some damage to Edmundston and Connors
1923	April 29-May 9	CNR and CPR closed at Quisbis; centre pier of Green River Bridge swept away
1933	May 4-6	At Fort Kent, river highest in 35 years; Saint John River at Edmundston highest since 1923
1936	March 16-25	Edmundston isolated; Ice jam at Quisbis, water over road and railway
1939	May 10-14	Some streets flooded in Fort Kent and Frenchville
1945	April 4-5	Spring freshet. Ice to Old Customs Building
1947	April 30-May 10	100 people evacuated at Fort Kent
1951	April 5-14	Flooded basements at Fort Kent; heavy erosion ten miles above Connors
1953	March 26-April 3	Mild temperatures caused heavy snowmelt
1954	September 11-13	Hurricane Edna

Table 4-1 (cont'd)

Flooding Events

Year	Date	Comments
1956	April 2	Saint John River 18" above Main Road at Quisbis and Green River
1958	April 24-30	Saint John River at Fort Kent 24.6 ft. above normal level
1961	May 8-12	Snowmelt. Water 2 to 3 ft. deep on Main street, Fort Kent with 35 homes, 65 commercial establishments and 4 public buildings flooded with up to 3 feet of water. Flood has a recurring interval of 50 years.
1961	May 25-31	Tropical Storms; basements flooded and highways inundated in Fort Kent area.
1969	May 11-13	Spring Freshet, heavy precipitation and snowmelt, Saint John River 6 ft. above normal at Edmundston. Flooding also at Sainte-Anne-de-Madawaska, Rivieré Verte and Edmundston
1974	April 29-May 8	Damage at Connors, Saint Francois, Clair, Caron Brook and Baker Brook. Ice jams at Fort Kent and Green River
1976	March 31-April 5	Bridge at Quisbis under 2 feet of water
1979	April 29-May 4	Storm with heavy snowmelt at Caron Brook, Baker Brook, Edmundston, Riviere Verte, Sainte-Anne-de-Madawaska and Siegas
1983	April 19	High flows at Edmundston
1987	April 2	Parking lot flooded at U.S. Customs - Van Buren

4.2 PRELIMINARY EVALUATION OF DATA

A summary of all flood information recovered during this study from the various sources is provided in Appendix I. A more detailed documentation of this information is provided in the Supplementary Field Report. Included within this listing are:

(i) all recovered photographs
(ii) descriptive newspaper reports
(iii) ice scars
(iv) documented high water elevations
(v) information provided by residents

The spatial distribution of historic flood documentation for events prior to 1991 is summarized in Table 4-2.

Table 4-2

Documented Flood Events/Community

	Location	Number of Points	Flood Years
1.	Saint Leonard/ Van Buren	17	1885, 1912, 1923, 1936, 1939, 1945, 1976, 1979, 1987
2.	Grand River	9	1976, 1979
3.	Sainte Anne de Madawaska	9	1939, 1953, 1976, 1987
4.	Quisbis	4	1936, 1951, 1953, 1976
5	Green River/ Saint Basile	12 2	1896, 1923, 1933, 1936, 1979 1885, 1987
6.	Edmundston	17	1898, 1933, 1936, 1958, 1961, 1976, 1979
8.	Baker Brook	11	1922, 1936, 1951, 1979
9.	Caron Brook	2	1923, 1974
10.	Clair/Fort Kent	22	1922, 1933, 1939, 1947, 1958, 1961

A total of 122 historic references to previous flooding events have been identified and documented in Appendix I. The list which includes 17 references to the 1991 flooding is comprehensive in that any reference to a previous flood event was recorded.

Of the 105 references to events prior to 1991 less than half were sufficiently detailed so as to identify a point in the field at which a water level could be surveyed to geodetic datum. In addition, not all of the water levels identified could be determined from the collected information with the same degree of accuracy. Therefore a ranking method was utilized to compare the reliability of the points obtained. The ranking system employed is similar to that utilized in previous flood studies and is summarized in Table 4-3. The range in vertical elevation indicated is considered to be a subjective interpretation of the ranked categories.

Table 4-3
Ranking of Reference Points

Description	Range
Good	± 25 mm
Reasonable	± 75 mm
Approximate	± 150 mm
Vague	± 300 mm
No point	N/A

The water level elevations determined for the 1991 event are all ranked as good.

4.3 FIELD RECONNAISSANCE AND SURVEY

A preliminary analysis was made of the 105 identified references to events prior to 1991 with a rating developed for the points which could be located in the field. These rankings were confirmed during the initial reconnaissance. During the field survey, some additional points were added while several points were deleted from the survey.

Utilizing established elevation control monuments (See Supplementary Field Report), the historic flood levels were determined at points identified from photographic documentation, historical reports, ice scars, etc. The position of the points was referenced to chainage information along the

centerline of the Saint John River. All points were surveyed to geodetic datum and referenced to N.B. Grid co-ordinates where possible.

The historic flood elevation along with its rating is presented for each surveyed point in Appendix I. A total of 67 points was located in the field and surveyed to geodetic datum. Of these points, 33 were based on photographs, 29 field identified points include ice scars and high water marks and 5 points were included from either Water Survey of Canada or United States Geological Society historical records. We were able to identify from photographs high water elevations in all major communities except Saint Basile and Saint Hilaire. In Saint Hilaire, several ice scars were located and identified. Following is a summary of the number of points identified in the field and the relative accuracy.

Rating	Number of Points
Good	27
Reasonable	12
Approximate	10
Vague	19

A summary of the points for flood events prior to 1991 by community along with the estimated probability of occurrence is presented in Table 4-4.

Table 4-4
Summary of Field Survey
(Events Prior to 1991)

	Location	Number of Points	Highest Historical Flood Elevation (m)[2]	Probability of Historical Event Occurrence (P)[1]
1.	Saint Leonard/Van Buren	6	136.7	.011
2.	Grand River	7	137.2	.045
3.	Saint Anne-de-Madawaska	8	139.0	.013
4.	Quisbis	2	137.4	.013
5.	Green River	4	140.6	.032
6.	Edmundston	6	141.9	.032
7.	Saint Hilaire	2	147.3	.250
8.	Baker Brook	6	151.8	.027
9.	Caron Brook	1	153.3	.027
10.	Clair/Fort Kent	8	157.3	.013

NOTE: (1) Refer to Section 6.1 for estimating procedure
$P = 1/T$ where T = recurrence interval in years.
(2) To Geodetic Datum

5.0 HYDROLOGY

The peak flows for each of the communities along the Saint John River were obtained by utilizing the "Guide to the Estimation of Flood Flows for New Brunswick Rivers and Streams" (15). This is referred to as the Regional Flood Engineering Analysis method. Application of the method is described in Appendix II. The peak flows determined for each community are summarized in Table 5-1.

As a secondary check on peak flows, single station flood frequency analyses were undertaken for relevant long term hydrometric stations on the Saint John River at Fort Kent (WSC Station 01AD002) and Grand Falls (WSC Station 01AF002). The comparisons indicated a close agreement between methods; the 20 year estimate of peak flows differed by an average of 3-4% and the 100 year values were found to differ by an average of 11-12% (See Appendix II).

The peak flows developed by the Regional Flood Frequency Analysis method as summarized in Table 5-1 were then used in the HEC-2 model for preliminary analysis of flood profiles.

Table 5-1
Summary of Flood Flows
Saint John River Flood Study

Study Area	Drainage Area (km^2)	Flood Flow, m^3/s Q20	Q100
Grand Falls (WSC Station 01AF002)	21900	5600	6417
Saint Leonard	21620	5534	6340
Siegas: d/s of Siegas River	21230	5444	6232
u/s of Siegas River	21130	5421	6204
Saint Anne de Madawaska	21070	5407	6188
Green River	19520	5047	5757
Saint Basile	19470	5035	5744
d/s of Madawaska River	18890	4900	5582
u/s of Madawaska River	15500	4100	4632
Baker Brook: d/s of Baker Brook	15250	4040	4562
u/s of Baker Brook	14800	3933	4435
Fort Kent (WSC Station 01AD002)	14700	3909	4406

6.0 ENVELOPE OF MAXIMUM FLOODING

6.1 PERCEPTION METHOD

A method of determining the probability distribution of flood levels from historical observations was developed by Gerard and Karpuk (4). For open water flood conditions, hydrometric records can be analyzed and transposed to the location of interest as discussed in Section 5.0. However, damage producing floods may be influenced by other factors such as spring ice breakup, ice jams and associated high water levels. Also, a significant amount of direct or indirect flood level observations may be available at a number of ungauged locations in a flood hazard area.

The Perception Method was utilized for this Study as a means of analyzing the frequency of occurrence of historical flood observations. The main advantage of the method is the ability to utilize historical and anecdotal flood level observations from a variety of sources. Ice jams and open water floods are considered together, thus resulting in identification and inclusion of additional information in the overall flood hazard analyses.

The main components of the analysis are:

(1) Collection and review of all sources of historical data discussed in Section 4.0 and summarized in Appendix I.

(2) Grouping of historical flood observations by communities.

(3) Determination of perception stages for each community and source of data. This is the flood level above which the source of information would have provided information on flood peaks.

(4) Identification of time periods of observations and recurrence interval of historical flood events.

The details of the analysis methodology and the results are discussed in Appendix III. The results of the analysis are summarized in Table 4-4 which gives the highest historical flood observation for each community prior to 1991 together with the estimated probability of occurrence. For

the purpose of this investigation, the estimated probability of occurrence of the maximum historical flood level at each location can be taken to be a measure of "conservatism" of the highest historical flood observation. For example, the observations at Saint Leonard/Van Buren represent a fairly long record length with the corresponding maximum historical level of 136.7 m occurring infrequently (P = .011). On the other hand, the short record length at Saint Hilaire indicates that the maximum level of 151.8 m occurs frequently (P = .250). Historical flood levels at the other locations can be interpreted in a similar way as an experience of the level of confidence in their use for identification of the local flood hazard.

The observed historical flood levels are summarized in Table 6-1 and plotted on Figures 6-1 to 6-5 for comparison to the 100 year open water flood profile.

6.2 OPEN WATER FLOOD LIMITS

The 20 and 100 year open water flood elevations, based on the peak flows presented in Section 5.0 were developed using a hydraulic computer model (HEC-2) obtained from N.B. Power. No additional model calibration was undertaken and it was assumed to be giving reasonable results for the purpose of this investigation. The model was previously calibrated by N.B. Power using peak flows and water levels available for the spring flood of 1979 and the August event of 1984. The main emphasis in the previous model application and calibration was the reach of river in the Study Area up to Edmundston. The previous calibration results are reported to be good (personal communication, S. Ismail, 1991). It was noted that less calibration was undertaken in the Edmundston to Fort Kent reach. Over the section of the area, the river bottom gradient is steeper and downstream Grand Falls plant influences do not extend above Edmundston. Peak instantaneous flows developed using regional regression equations were used in the HEC-2 model for analysis.

The detailed model input and output is available on computer diskette as part of the background information for this Study. The peak water levels at selected locations are summarized in Table 6-1 for comparison to maximum historical observed flood elevations. The 100 year flood profile is summarized on Figures 6-1 to 6-5 for the Study Area.

Table 6-1

Inferred Historic and Open Water Flood Elevations

Station (m)	Historic Flood Elevation (m)[1]	100 Year Flood Elevation (m)[1]	Comments
0 + 00	--	--	Study Limit
1 + 17	--	138.3	Saint Leonard - Downstream
2 + 00	126.8	138.3	Initial Highway Bridge, Saint Leonard
3 + 51	126.9	138.9	Saint Leonard - Upstream
5 + 86		139.4	Downstream, confluence Grand River/Saint John River
7 + 48	137.2	139.5	Grand River Upstream
15 + 19	138.9	140.1	Saint Anne-de-Madawaska - Downstream
16 + 77	139.2	140.3	Confluence of Quisbis & Saint John Rivers
17 + 00	139.2	140.3	Match Line
18 + 42	139.4	140.5	Saint Anne-De-Madawaska-Upstream
27 + 38	140.7	141.8	Confluence of Green & Saint John Rivers
28 + 02	148.8	142.1	Green River - Downstream/Upstream
33 + 72	141.1	142.6	Saint Basile - Downstream
34 + 00	141.1	142.7	Match Line

Note: Flood elevations indicated inferred from water surface profiles on Figures 6-1 to 6-5.

(1) Geodetic Datum

Table 6-1 (cont'd)

Inferred Historic and Open Water Flood Elevations

Station (m)	Historic Flood Elevation (m)	100 Year Flood Elevation (m)	Comments
40 + 21	142.2	143.1	Saint Basil Upstream
43 + 17	143.2	143.5	Edmundston - Downstream Confluence of Madawaska River
43 + 89	143.4	143.5	Water Level Gauge
48 + 00	144.3	145.1	Edmundston (Upstream)
51 + 00	144.9	146.6	Match Line
55 + 88	146.6	149.3	Saint Hilaire - Downstream
57 + 40	147.2	149.6	Saint Hilaire - Upstream
65 + 82	150.5	151.7	Baker Brook - Downstream
67 + 13	151.1	152.0	Confluence of Baker Brook/ Saint John River
68 + 00	151.4	152.1	Match Line
68 + 06	151.4	152.1	Baker Brook - Upstream
77 + 75	156.2	158.2	Clair - Downstream
78 + 76	157.0	158.8	Water Level Gauge @ Fort Kent
79 + 51	157.6	159.0	Confluence of Fish & Saint John Rivers
80 + 07	157.9	158.9	Initial Highway Bridge at Clair
82 + 68		160.3	Clair - Upstream
84 + 08		160.8	Study Limit

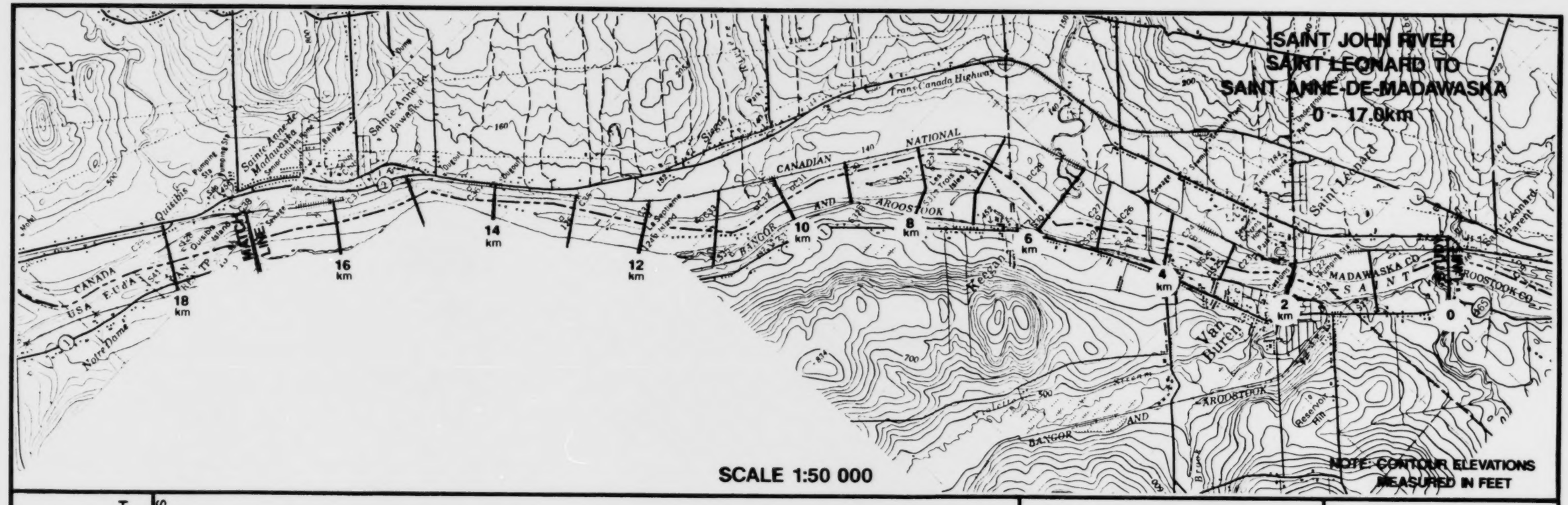

SAINT JOHN RIVER
SAINT LEONARD TO
SAINT ANNE-DE-MADAWASKA
0 - 17.0km
SCALE 1:50 000
NOTE: CONTOUR ELEVATIONS MEASURED IN FEET
MATCH LINE
QUISIBIS RIVER
GRAND RIVER
INTL BRIDGE
STUDY LIMIT
100 YEAR FLOOD PROFILE
HISTORIC FLOOD PROFILE
HISTORIC HIGH WATER ELEVATION AND NUMBER
RIVER BOTTOM (N.B. POWER)
ELEVATION (METRES) GEODETIC DATUM
RIVER CHANNEL DISTANCE (KILOMETRES)

FIGURE 6-1

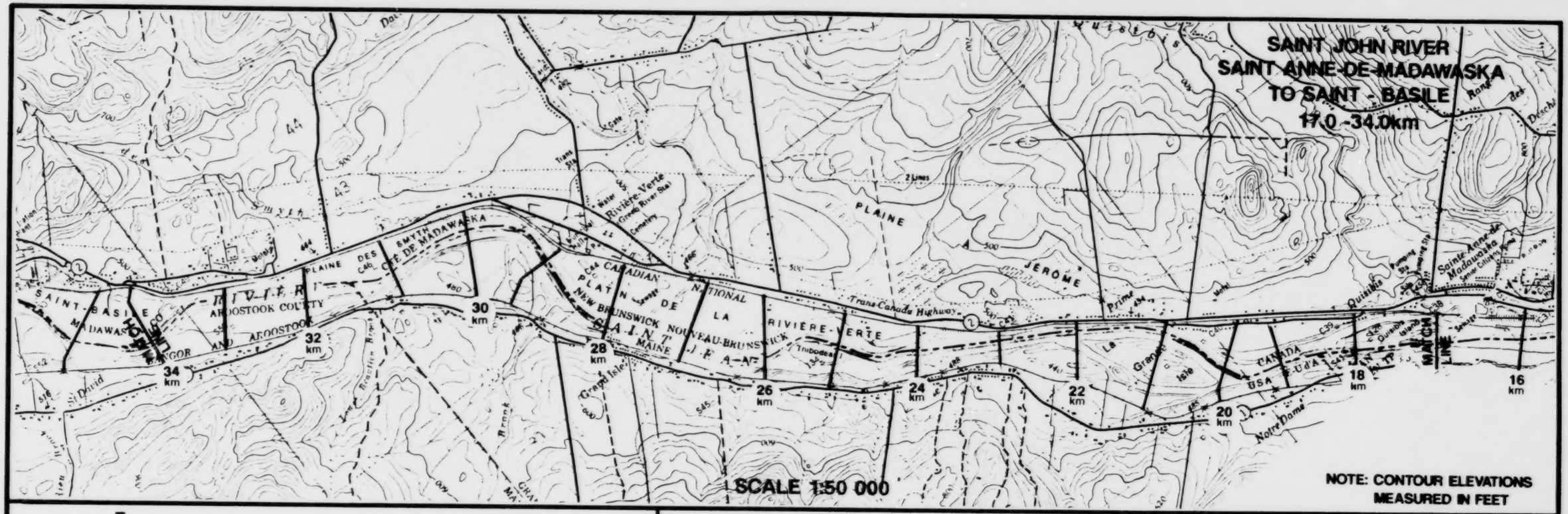

SAINT JOHN RIVER
SAINT ANNE-DE-MADAWASKA
TO SAINT - BASILE
17.0 -34.0km
SCALE 1:50 000
NOTE: CONTOUR ELEVATIONS
MEASURED IN FEET
MATCH LINE
GREEN RIVER
100 YEAR
FLOOD PROFILE
HISTORIC FLOOD PROFILE
HISTORIC HIGH WATER
ELEVATION AND NUMBER
RIVER BOTTOM
(N.B. POWER)
ELEVATION (METRES)
GEODETIC DATUM
RIVER CHANNEL DISTANCE (KILOMETRES)
506
505
504
502
521E
501
503
408E
407E
406E
402
403
307
144
140
136
132
128
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17

FIGURE 6-2

SAINT JOHN RIVER
SAINT - BASILE TO
SAINT - HILAIRE
34.0 - 51.0km

SCALE 1:50 000

NOTE: CONTOUR ELEVATIONS MEASURED IN FEET

MATCH LINE

INTL BRIDGE

MADAWASKA RIVER

100 YEAR FLOOD PROFILE

HISTORIC FLOOD PROFILE

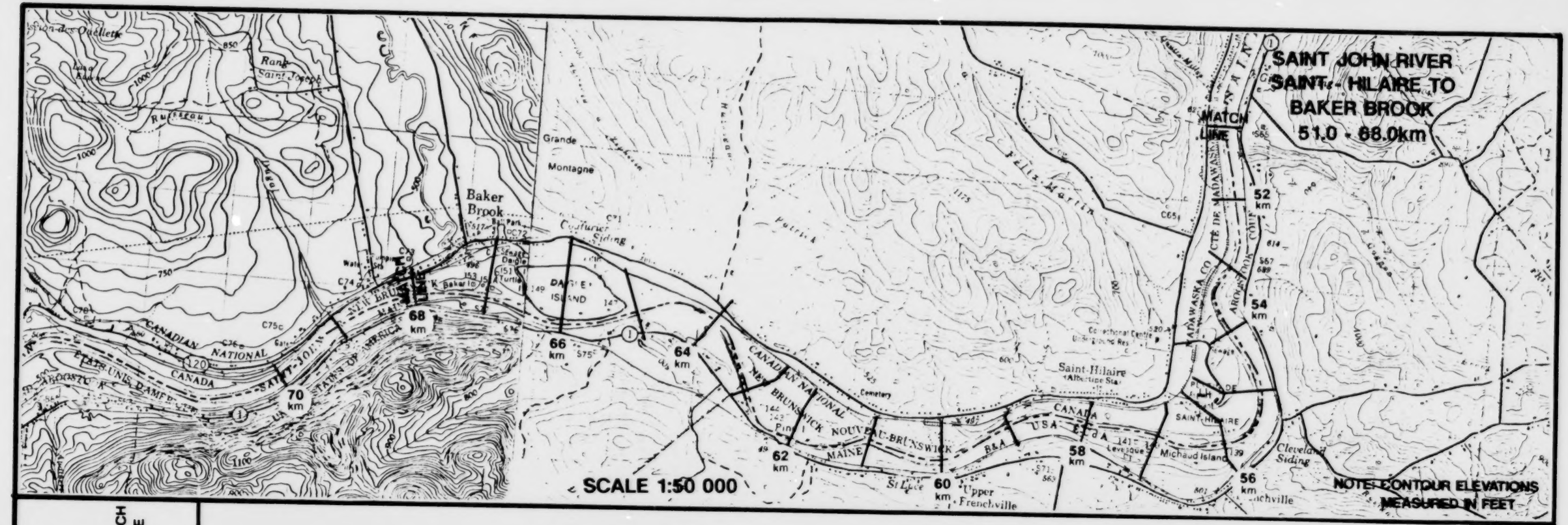
HISTORIC HIGH WATER ELEVATION AND NUMBER

RIVER BOTTOM (N.B. POWER)

ELEVATION (METRES) GEODETIC DATUM

RIVER CHANNEL DISTANCE (KILOMETRES)

FIGURE 6-3


SAINT JOHN RIVER
SAINTE-HILAIRE TO
BAKER BROOK
51.0 - 68.0km
MATCH LINE
Baker Brook
Grande Montagne
Saint-Hilaire
Michaud Island
Cleveland Siding
Upper Frenchville
CANADIAN NATIONAL
CANADA
USA
MAINE
NEW BRUNSWICK
NOUVEAU-BRUNSWICK
68 km
66 km
64 km
62 km
60 km
58 km
56 km
54 km
52 km
70 km
SCALE 1:50 000
NOTE: CONTOUR ELEVATIONS MEASURED IN FEET

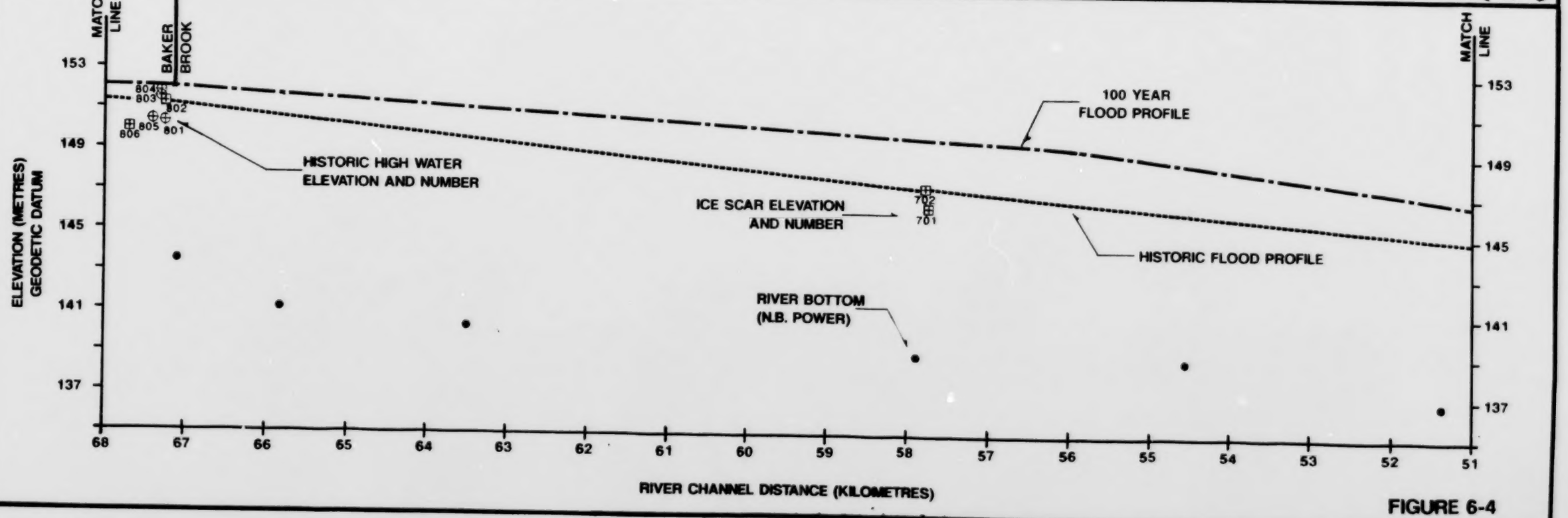
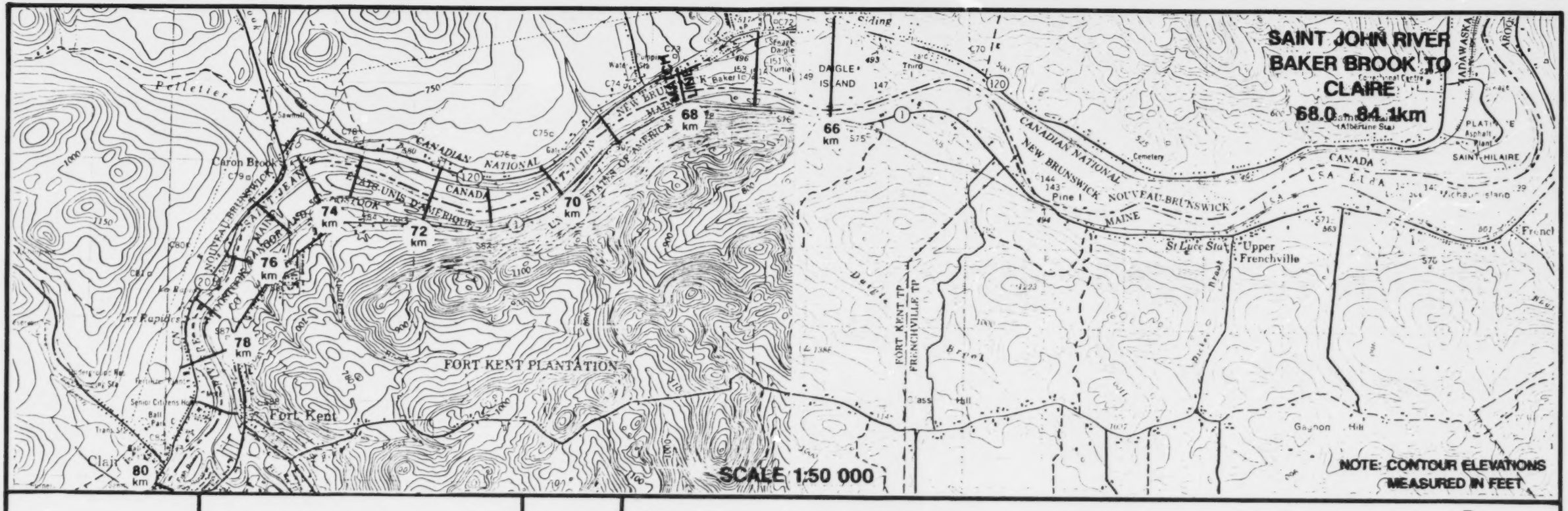

MATCH LINE
BAKER BROOK
MATCH LINE
100 YEAR FLOOD PROFILE
HISTORIC HIGH WATER ELEVATION AND NUMBER
ICE SCAR ELEVATION AND NUMBER
HISTORIC FLOOD PROFILE
RIVER BOTTOM (N.B. POWER)
ELEVATION (METRES) GEODETIC DATUM
153
149
145
141
137
804
803
802
805
806
801
702
701
68 67 66 65 64 63 62 61 60 59 58 57 56 55 54 53 52 51
RIVER CHANNEL DISTANCE (KILOMETRES)

FIGURE 6-4


SAINT JOHN RIVER
BAKER BROOK TO
CLAIRE
68.0 - 84.1km
SCALE 1:50 000
NOTE: CONTOUR ELEVATIONS
MEASURED IN FEET
FORT KENT PLANTATION
Fort Kent
Perletier
Caron Brook
Les Rapides
DAGLE
ISLAND
Pine I
St Luce Stn
Upper
Frenchville
Gagnon Hill
FORT KENT TP
FRENCHVILLE TP
CANADIAN NATIONAL
CANADA
NEW BRUNSWICK
NOUVEAU-BRUNSWICK
MAINE
ETATS-UNIS D'AMERIQUE
SAINT-JEAN
SAINT-JOHN
68 km
70 km
72 km
74 km
76 km
78 km
80 km
66 km

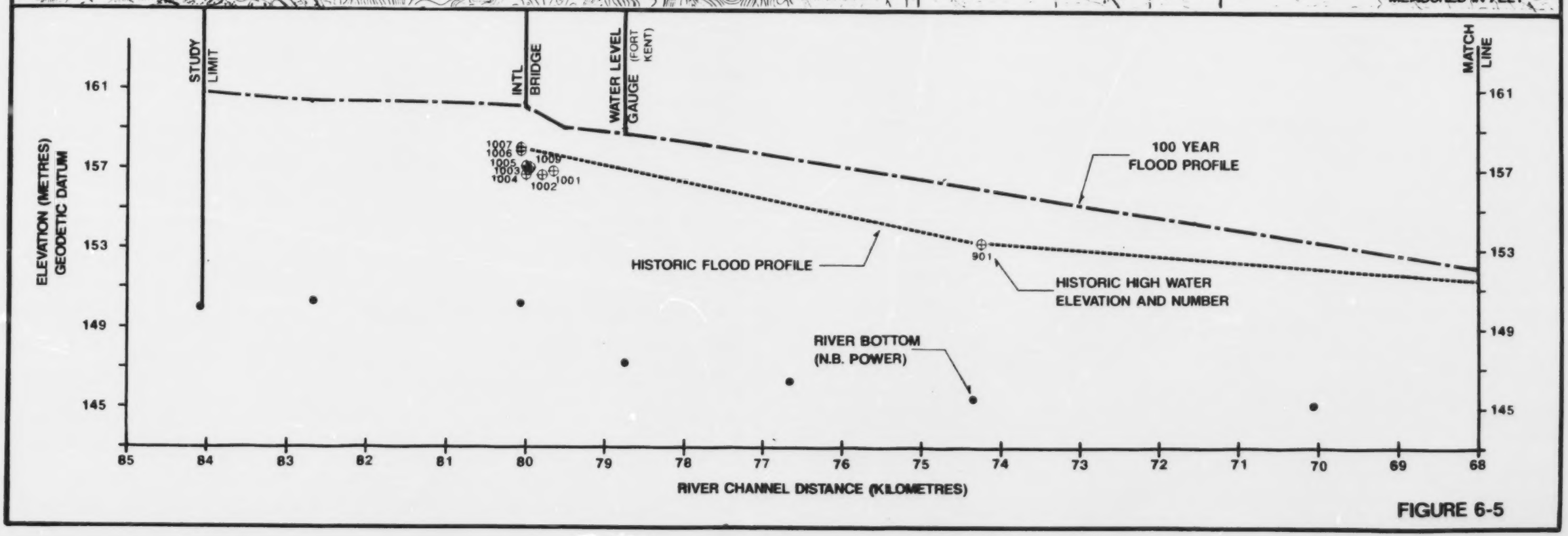

STUDY LIMIT
INTL BRIDGE
WATER LEVEL GAUGE (FORT KENT)
MATCH LINE
ELEVATION (METRES) GEODETIC DATUM
161
157
153
149
145
100 YEAR FLOOD PROFILE
HISTORIC FLOOD PROFILE
HISTORIC HIGH WATER ELEVATION AND NUMBER
RIVER BOTTOM (N.B. POWER)
1007
1006
1005
1003
1004
1002
1009
1001
901
85 84 83 82 81 80 79 78 77 76 75 74 73 72 71 70 69 68
RIVER CHANNEL DISTANCE (KILOMETRES)

FIGURE 6-5

Comparative open water flood calculations were obtained for the Town of Fort Kent (17). The range of flood levels in Fort Kent for the present study (158.2 - 160.3 m) was found to be comparable to that previously recorded on the flood insurance map. The average flood level on the latter was found to be 159.8 m. This indicates a close agreement between the results of the two investigations thus increasing the level of confidence that can be placed on this preliminary application of the available HEC-2 model.

6.3 IDENTIFICATION OF REMEDIAL MEASURES

In summary, the floodlines determined from the flood profiles illustrate flooding in each of the communities as described as follows:

Saint Leonard

- basically contained by RR tracks
- no residences affected
- Canada Customs parking lot may be overtopped
- no significant damage

Saint Anne-de-Madawaska

- some residence flooding at Green River
- significant flooding between Quisbis and Green River (50 residences affected)
- a number of residences have been affected at Grand River particularly in trailer park

Possible Remedial Measures:

- Build up Trans-Canada Highway 1.0-1.5 m to act as berm.

Green River

- no apparent danger to residences

Siegas

- residences appear safe from 100 year flooding

Saint Basile

- widespread flooding over Saint Basile flats
- sewage treatment lagoon in flood risk area
- no residences affected

Possible Remedial Measures:

- Berming
- Raise berns of sewage treatment lagoon

Edmundston

- flooding contained by RR tracks
- no development on flood plain

Baker Brook

- significant flooding in overbank areas (i.e. Couturier Siding)
- ten or more residences affected at confluence of Baker Brook

Possible Remedial Measures:

- Floodproof each unit
- Berm lower reach of Baker Brook

Clair/Fort Kent

- widespread flooding in overbank areas although residential flooding minimal

Possible Remedial Measures:

- Fort Kent has constructed protective berms

7.0 DISCUSSION

The results presented in Table 6-1 and graphically on Figures 6-1 to 6-5 indicate that the probability analysis of historical flood data using the Perception Method are fairly consistent with open water flood levels obtained from HEC-2 modelling. For example, based on the Perception Method analysis, none of the historic events recalled or researched has a return period in excess of 100 years and, similarly, none of the historic elevations are greater than the computed 100 year elevations. In areas such as Clair/Fort Kent where the estimated return period for the most severe historical event recalled approaches 100 years the historic flood elevation is also relatively close to the 100 year computed flood elevation.

Of all the most severe events summarized in Table 6-1, only the Saint Leonard/Van Buren and Grand River floods of 1979 coincide with extreme peak flows measured at nearby WSC gauging stations. Considering the time of year of the occurrence (April 30), the high flow was likely due to a combination of heavy rainfall and snowmelt. The peak historical events of 1976 (Sainte Anne-de-Madawaska and Green River) and 1978 (Edmundston and Baker Brook) are probably ice-related as the peak flow recorded for those years is not excessive. In addition, the most severe event recalled/documented for the community of Saint Hilaire was definitely ice-related. Therefore, this study has confirmed that the most severe events that can be recalled in the Study Area are associated with rainfall and/or snowmelt conditions. The fact that fewer historical events have ice jam complications is also reflected in the fact that the computed 100 year open water flood profiles are generally higher than the maximum observed historical flood events i.e. the latter are therefore not generally the result of severe ice jams.

Hydrometric records at Clair/Fort Kent, Edmundston and Grand Falls indicate that the 1979 annual maximum instantaneous flow recorded the rainfall plus snowmelt condition noted previously, was equivalent to or just slightly less than the 100 year peak flow. However, documentation of flooding in these areas is limited. The community of Grand Falls was not included in the survey and, while Edmundston and Clair reported flooding, no high water level marks could be identified for this Study. This does not mean that flooding due to the 1979 event was not more extensive than for other events that were recalled but perhaps that the duration of the peak flow was less and the extent of damage due to the nature of the flood was

less, thereby not having as big an impact in the minds of the area residents.

In conclusion, in our opinion it is evident that flood hazard identification should be based on the 100 year open water flood profile along the Study Area, except where evidence indicates that historical flood events are higher. For comparison purposes the available observations of historical flood levels appear to be a reasonable data set reflecting the high flood hazard in the Study Area.

8.0 REFERENCES

1. Kindervater, A.D. 1988. Flooding Levels in New Brunswick, An Historical Perspective. IWD-ARE-WPMB-84-65. Environment Canada Inland Waters Directorate, Dartmouth, Nova Scotia.

2. Inland Waters Directorate, Atlantic Region and New Brunswick Department of Environment, 1981. The Flood of 1979 Saint John River Basin New Brunswick, Report T-8101.

3. Department of Energy, Mines and Resources, Inland Waters Branch. 1967. Floods of 1961 in New Brunswick. Water Resources Paper No. 134F, Ottawa.

4. Department of Environment, Water Planning and Operations Branch, 1971. Summary of Newspaper Reports on Flooding in the Saint John River Basin-Saint John Telegraph Journal. Unpublished.

5. Department of Environment, Inland Waters Directorate, 1974. New Brunswick Flood, April - May, 1973, Technical Bulletin No. 81, Halifax.

6. Department of Public Works, New Brunswick District, 1970. Engineering Report of Flood Damage to Highway and Hydro-Electric Systems in the Province of New Brunswick.

7. Zinck, J.B., 1979. Engineering Report on Flood Damage in the Province of New Brunswick, Spring of 1979, Department of Public Works, Atlantic Region.

8. LeBrun-Salonen, Melanie L., 1983. The March 1936 Ice Jam Flood in New Brunswick. A report prepared under the New Employment Expansion Development Program, J.E. Peters Management Limited.

9. LeBrun-Salonen, Melanie L., 1984. The February 1970 Ice Jam Floods in New Brunswick. A report prepared under the Canada Works Program, J.E. Peters Management Limited.

10. LeBrun-Salonen, Melanie L., 1984. The April 1950 Ice Jam Floods in New Brunswick. A report prepared under the Canada Works Program, J.E. Peters Management Limited.

11. DeMerchant, C.R. 1989. Saint John River Spring Breakup. Beechwood Dickey, Me. 1989.

12. Hughes, John C. The Upper Saint John River. Some Personal Reflections.

13. Langton, J.G.P. 1976. Spring Flooding In New Brunswick. N.B. EMO New Brunswick Emergency Measures Organization.

14. USCE. 1982. HEC-2 Water Surface Profile Users Manual. U.S. Army Corps of Engineers, Hydrologic Engineering Centre, Computer Program 723-X6-L202A, California.

15. Department of Municipal Affairs and the Environment, 1987. New Brunswick Flood Frequency Analysis - A Guide to the Estimation of Flood Flows for New Brunswick Rivers and Streams. Fredericton, New Brunswick.

16. Gerard, R. and E.W. Karpuk. 1979. Probability Analysis of Historical Flood Data. ASCE, Journal of the Hydraulics Division, Sept.

17. U.S. Federal Emergency Management Agency. 1984. Flood Insurance Rate Map - Town of Fort Kent.

APPENDIX I

HISTORIC FLOOD DOCUMENTATION

Appendix I

Historic Flood Documentation

The flood documentation aspect of the Study involved the collection and assessment of all historical flood data by contacts made with public and private organization, local authorities and residents and an archival research. All collected information was compiled and assessed as to its accuracy. A total of 122 historic references to previous flooding consisting of 17 points from the 1991 flood event and 105 from events prior to 1991 were identified and are documented in the following Table I-1. The list is comprehensive in that any reference to a previous flood event has been recorded.

The numbering system for adopted for this Study and used to identify each of the 122 identified points is shown in the left hand column of Table I-1. The Study Area encompasses the area prone to flooding along the Saint John River, between the communities of Saint Leonard [1] and Clair [10] and includes the comunities of Grnad River [2], Saint-Anne-de Madawaska [3], Quisbis [4], Rivieré Verte [5], Edmundston [6], Saint HIlaire [7], Baker Brook [8] and Caron Brook [9]. The bracketed number after each community refers to the designated identificaiton number which has been assigned to the community for the Study and to which historic flood elevations have been referenced.

The date indicated refers to the year in which the point was identified while the various sources of this information are summarized in the adjacent columns.

The ranking method utilized to compare the reliability of the points obtained, which is similar to that utilized in previous flood studies, and is summarized as follows. The range in vertical elevation indicated is considered to be a subjective interpretation of the ranked categories.

Ranking of Reference Points

Description	Range
Good	± 25 mm
Reasonable	± 75 mm
Approximate	± 150 mm
Vague	± 300 mm
No point	

Table I-1
Historic Flood Documentation

Point No.	*Description*	*Date*	*Source*	*Rating*	*Elevation*
Saint Leonard/ Van Buren					
101.	Photo showing high water along Pumphouse Road	1979	NB Power	Reasonable	136.46
102.	Photo showing International Bench Mark at St. Leonard	1979	NB Power	Reasonable	136.73
103.	Photo showing U.S. customs parking lot	1987	E. Flewelling	Vague	133.04
104.	Photo showing high water on building immediately north of Customs building	1979	E. Flewelling	Reasonable	136.44
105.	Aerial photograph of building adjacent U.S. Customs	1976	NB Power	Vague	134.70
106.	High water mark indicated by Spike on barn	1979		Good	136.54
107.	River rose 16 feet at Van Buren (in July)	1885	ADK Report	Vague	
108.	Saint John River now 8 feet above normal (in August)	1912	ADK Report	No Point	
109.	Reference to water dropping 5 feet at St. Leonard	1923	Newspaper	No Point	
110.	Photo showing street flooding, home shown	1930	Archives	No Point	
111.	Water 4' from bottom of Van Buren International Bridge	1936	Newspaper	No Point	
112.	CPR bridge collapse at St. Leonard	1936	ADK Report	No Point	
113.	Photo showing pier in river at distance during high flow	1939	J. Hughes	No Point	
114.	Photo showing pier with broken ice surrounding	1939	J. Hughes	No Point	
115.	Island No. 6 with ice to it, broken ice jam	1939	J. Hughes	No Point	

Point No.	Description	Date	Source	Rating	Elevation
116.	Photo showing ice in front of buildings in Saint Leonard	1945	Lapoint	No Point	
Grand River					
201.	Photo of Grand River Campground - sign post	1979	NBDOE	Reasonable	136.77
202	Painted high water mark on Grand River Bridge abutment	1979	Unknown	Good	137.20
203.	Photo of Grand River Highway Bridge	1979	NB Power	Reasonable	137.20
204.	Aerial photo upstream of Grand River showing flooded road	1976	NB Power	No Point	
205.	Photo of trailer park at Grand River	1979	NBDOE	Approximate	137.15
206.	Photo immediately south of Grand River	1979	NB Power	Reasonable	137.11
207.	Photo of Grand River Campground	1979	NB Power	No Point	
208	Photo of Grand River Campground at tree line	1979	NBDOE	Reasonable	137.10
209.	Photo of Grand River Campground	1979	NB Power	Approximate	135.90
Sainte Anne-de-Madawaska					
301.	Aerial photograph of flooding	1976	NB Power	Vague	138.96
302.	Photo of Saint Anne Lagoon Road, ground level	1987	NB Power	Vague	137.35
303.	Photo showing house flooding, logs around building	1953	Lapoint	Vague	136.42
304	High water point identified by resident	1976	Unknown	Approximate	138.41

Point No.	Description	Date	Source	Rating	Elevation
St. Anne-de-Madawaska					
305.	Photo showing railway tracks before bend	1976	NB Power	Vague	138.9
306.	Photo showing highway overtopped in front house at St. Anne & pole	1976	NB Power	Approximate	138.85
307.	Photo showing ground level photo of bridge	1976	NB Power	Approximate	138.73
308.	Photo showing ice and water to bottom chord of bridge	1953	Lapoint	Approximate	136.64
309.	Photo showing broken ice in Saint John River behind house	1939	J. Hughes	No Point	
310E	High Water Mark	1991	NBDOE	Good	135.88
311E	High Water Mark	1991	NBDOE	Good	136.89
312E	High Water Mark	1991	NBDOE	Good	137.95
Quisibis					
401	Bridge at Quisibis under two feet of water	1951	Newspaper	Vague	138.71
402.	Photo showing flooded road in front of local resident	1953	Lapoint	Vague	137.45
403	Farm at Quisbis River	1991	Nolan Davis	Reasonable	
404.	Water over railway, highway & telephone lines out	1936	ADK Report	No Point	
405.	Ice jam at aerial photo showing flooding over highway	1976	NB Power	No Point	
406E	High Water Mark	1991	NBDOE	Good	138.62
407E	High Water Mark	1991	NBDOE	Good	139.20
408E	High Water Mark	1991	NBDOE	Good	139.47

Point No.	Description	Date	Source	Rating	Elevation
Green River					
501.	Photo of CN Bridge from Highway	1979	NBDOE	Vague	139.41
502.	Aerial photo of CN Bridge over Green River	1976	NB Power	Vague	140.67
503.	Photo of flooded highway at Green River	1979	NB Power	Vague	138.93
504.	Aerial photo with highway sign, water in front of houses	1976	NB Power	Approximate	140.19
505.	First house off the Trans Canada Highway	1991	Nolan Davis	Good	
506.	Dirt road upstream of Green River	1991	Nolan Davis	Good	139.43
507.	Saint Basile dirt road downstream of town	1991	Nolan Davis	Good	137.76
508.	Sainte Basile at cemetary and small museum	1991	Nolan Davis	Good	141.00
509.	Sainte Basile at hollow near paint shop	1991	Nolan Davis	Good	141.55
510.	Iroquois Trailer Part at Iroquois River Bridge	1991	Nolan Davis	Good	142.22
511.	Ice jam submerged tracks to 5 ft. Water submerged tracks at Green River	1896	ADK Report	No Point	
512.	Centre pier swept away	1923	ADK Report	No Point	
513.	Main highway near Green River under several feet of water	1933	ADK Report	No Point	
514.	Bridge No. 2 in grave danger	1936	Newspaper	No Point	
515.	Water 18" above main road between Quisbis & Green River	1956	Newspaper	No Point	
516.	Ice damaged cottages at Green River	1974	ADK Report	No Point	
517.	Part of Green River Campground, ground level	1979	NB Power	No Point	
518.	Photo of Highway bridge before peak	1979	NBDOE	No Point	

Point No.	Description	Date	Source	Rating	Elevation
Saint Basile					
519.	St. Basile flats flooded	1885	Newspaper	No Point	
520.	Photo showing Ice run at St. Basile	1987	NB Power	No Point	
521E.	High Water Mark	1991	NBDOE	Good	140.38
Edmundston					
601.	Photo showing house on Ferry Street	1961	Lapoint	Approximate	140.68
602.	Water crossed today at Traverse Street	1969	Newspaper	Vague	140.42
603.	Traverse Street	1979	Unknown	Vague	141.93
604.	Water Survey of Canada Gauge	1979	WSC	Good	141.7
605.	Water Survey of Canada Gauge	1983	WSC	Good	141.04
606	Water Survey of Canada Gauge	1987	WSC	Good	140.24
607.	Water over Victoria Street	1898	ADK Report	No Point	
608.	Railway traffic halted due to flooding	1933	ADK Report	No Point	
609.	Water 15' over railroad tracks	1936	Newspaper	No Point	
610.	Photo of 30 Ferry Street home	1958	Newspaper	No Point	
611.	Water surround house at 30 Ferry St.	1958	Newspaper	No Point	
612.	Water surround house at 30 Ferry St.	1961	Newspaper	No Point	
613.	High water on Transverse Street	1991	Nolan Davis	Good	143.43
614.	Water level 16 feet above normal	1969	ADK Report	No Point	
615.	Two feet of water over Boy Scout Camp Flats	1969	Newspaper	No Point	

Point No.	Description	Date	Source	Rating	Elevation
Edmundston					
616.	Water in basement	1969	Newspaper	No Point	
617.	Water over TCH at Wandlyn Inn	1976	ADK Report	No Point	
Sainte Hilaire					
701	Highwater mark (leaves & other debris)	--	Scar	Good	146.25
702	Ice scar	--	Scar	Vague	147.28
Baker Brook					
801.	Highwater mark	1974	Unknown	Approximate	150.28
802.	Ice scar	--	Scar	Vague	151.20
803.	Photo of water at guard rail	1979	NBDOE	Good	151.76
804.	Photo near ranger station	1979	NBDOE	Approximate	151.78
805.	Photo of highwater mark on bridge	1979	NBDOE	Vague	150.42
806.	Ice scar	--	Scar	Vague	149.99
807.	High water on barn above D.N.R.	1991	Nolan Davis	Approximate	151.42
808.	Fraser's mill dam partially destroyed	1922	Newspaper	No Point	
809.	Covered bridge at Baker Brook out	1936	Newspaper	No Point	
810.	Water approached CNR main line	1951	ADK Report	No Point	
811.	Water rose 7' over Temicoste RR	1951	Newspaper	No Point	
812.	Photos of water near house	1979	NBDOE	No Point	

Point No.	Description	Date	Source	Rating	Elevation
Caron Brook					
901	Water crossed road	1974	Unknown	Vague	154.30
902.	Bridges washed out	1923	ADK Report	No Point	
Clair - Fort Kent					
1001.	Photo showing Maine Public Service Scene	1961	Lapoint	Reasonable	156.86
1002.	Photo showing Tastee-freeze - pumps	1961	Lapoint	Good	156.68
1003.	Photo showing Sunoco street scene - hydrant	1961	Lapoint	Reasonable	156.92
1004.	Photo showing back of houses in Fort Kent - rooming	1961	Lapoint	Approximate	156.70
1005.	Photo of water in front of rooming house	1974	Unknown	Vague	157.13
1006.	Highwater mark on bridge abutment	--	Unknown	Good	147.88
1007.	USGS Gauge	1961	WSC	Good	156.90
1008.	USGS Gauge	1979	WSC	Good	157.30
1009.	High water at International Bridge	1991	Nolan Davis	Good	157.19
1010.	Some inundation of Front Street	1922	ADK Report	No Point	
1011.	Water level highest in 35 year period	1933	ADK Report	No Point	
1012.	Some people forced to evacuate due to high waters Water level highest since 1923	1939	ADK Report	No Point	
1013.	Flood caused evacuation of 100 people	1947	ADK Report	No Point	
1014.	Water level 20 feet above normal	1958	Newspaper	No Point	
1015.	Water Four feet below bridge deck	1958	ADK Report	No Point	

Point No.	Description	Date	Source	Rating	Elevation
1016.	Water 2 to 3 feet over Main Street	1961	ADK Report	No Point	
1017.	Photo showing Charette Plumbing	1961	Lapoint	No Point	
1018.	Water on road at Fort Kent	1969	Newspaper	No Point	
1019.	Water four feet below bridge deck	1958	Newspaper	No Point	
1020.	Buildings along Main Street in Clair		Archives	No Point	
1021.	Photo of Bridge at Clair		Archives	No Point	
1022.	Clair Rock - multiple W/L		Unknown	No Point	

APPENDIX II

HYDROLOGY

APPENDIX II

HYDROLOGY

II.1 GENERAL

The peak flows for each of the communities along the Saint John River were obtained by two conventional methods, namely:

(i) Regional Flood Frequency Analysis, and

(ii) Single Station Frequency Analysis.

These methods are detailed in the following sections.

II.2 REGIONAL FLOOD FREQUENCY ANALYSIS

The regional regression equations (15) were available for the entire study area for the 2, 10, 20, 50 and 100 year return periods in the following form:

$$\log_{10} QDT = k + a \log_{10} DA + b \log_{10} MAP$$

where QDT is the annual maximum daily mean flow (m^3/s) with a recurrence interval of T years;

k is the regression constant;

a and b are the regression coefficients;

DA is the drainage area (km^2); and,

MAP is the mean annual precipitation (mm).

(Only 20 and 100 year return period flows are determined for this Study).

The equations for the Saint John River main stem region were utilized. The regression coefficients were obtained by referring to Tables II-1 (after Table 5 of Reference 15).

The drainage areas for each location were obtained by referencing previously completed reports of the Study Area, Water Survey of Canada

documents and available mapping. A summary of the drainage areas used is presented in Table 5-1.

Maximum daily mean and instantaneous peak flows developed using the Regional regression equations are summarized in Table II-6. Instantaneous peak flows developed by the regression equations were used in the HEC-2 model for analysis.

II.3 SINGLE STATION FREQUENCY ANALYSIS

As a secondary check, frequency analyses were performed on historical flow data at stations along the system which were pertinent to the current study, namely; Fort Kent (WSC station 01AD002), Edmundston (WSC station 01AD004) and Grand Falls (WSC station 01AF002). Although Grand Falls is downstream of the Study Area, return period flows at this location may be prorated upstream based on a ratio for drainage areas. Two pro-rating methods were used; one based on the direct ratio of drainage areas and the second using an adjusted ratio according to the regression exponent for the area term. Similarly, return period flows determined for Edmundston may be prorated upstream to provide flows at, say Baker Brook.

Historical data up to 1985 was also used to derive the regional relationships. Application of the Single Station analysis utilized more up-to-date data and confirmed results of Regional Regression equations at specific locations.

The results of the Single Station Analysis for the above-noted stations are presented in Table II-2, II-3, II-4. Maximum daily data was used in the analyses due to generally longer word lengths. The sample size for station 01AD004 was found to be too short in the purposes of this comparison analysis and is not considered further.

Table 5-1 summarizes the results of Regional Flood Frequency Analysis and the Single Station Frequency Analysis. Peak flows for locations between gauging stations were developed by the prorating technique described earlier. Generally, the results of the Single Station Analysis and the Regional Frequency Analysis are in close agreement. The 20 year estimates differ by an average of 3-4%. The 100 year estimates differ by an average of 11-12% for the two methods of pro-rating single station values.

The results of the secondary analysis confirmed the use of the regression method. The maximum daily values were then adjusted by the peaking factor and input to the HEC-2 model.

TABLE II-1

REGIONAL REGRESSION EQUATIONS

$$\log_{10}QDT = k + a\log_{10}DA + b\log_{10}MAP$$

Return Period (yrs)	Region	k	a	b	Multiple r-square	Standard Error (%)
2	Province	-0.420	0.913	-	0.978	+21.3, -17.6
		-4.146	0.933	1.206	0.984	+18.1, -15.4
	Eastern	-0.650	1.001	-	0.962	+13.8, -12.1
	Central	-0.570	0.965	-	0.997	+11.8, -10.6
	Southern	-0.181	0.840	-	0.957	+26.7, -21.1
		-10.626	0.894	3.343	0.993	+10.8, - 9.8
	Northwestern	-0.706	0.995	-	0.987	+14.6, -12.7
	Saint John main stem	-0.062	0.836	-	0.999	+ 2.8, - 2.7
10	Province	-0.146	0.888	-	0.967	+26.3, -20.8
		-5.696	0.918	1.797	0.981	+19.7, -16.5
	Eastern	0.059	0.786	-	0.974	+ 8.8, - 8.1
	Central	-0.290	0.949	-	0.996	+11.8, -10.6
	Southern	-0.021	0.881	-	0.957	+28.0, -21.8
	Northwestern	-0.548	1.004	-	0.980	+19.2, -16.1
	Saint John main stem	-0.142	0.882	-	0.998	+ 4.1, - 3.9
20	Province	-0.055	0.878	-	0.960	+29.1, -22.5
		-6.170	0.910	1.980	0.977	+21.6, -17.8
	Eastern	0.368	0.684	-	0.957	+ 9.9, - 9.0
	Central	-0.190	0.939	-	0.996	+12.6, -11.2
	Southern	0.039	0.887	-	0.958	+28.0, -21.9
	Northwestern	-0.509	1.009	-	0.976	+20.9, -17.3
	Saint John main stem	-0.188	0.901	-	0.998	+ 4.4, - 4.3

TABLE II-1 (continued)

REGIONAL REGRESSION EQUATIONS

$$\log_{10}QDT = k + a\log_{10}DA + b\log_{10}MAP$$

Return Period (yrs)	Region	k	a	b	Multiple r-square	Standard Error (%)
50	Province	0.052	0.864	-	0.948	+33.3, -25.0
		-6.759	0.900	2.206	0.970	+24.9, -19.9
	Eastern	0.759	0.552	-	0.872	+14.7, -12.9
	Central	-0.078	0.930	-	0.994	+15.4, -13.3
		-11.195	0.986	3.571	0.999	+ 7.9, - 7.3
	Southern	0.110	0.892	-	0.958	+28.2, -22.0
	Northwestern	-0.470	1.017	-	0.972	+23.3, -18.9
	Saint John main stem	-0.269	0.928	-	0.998	+ 4.5, - 4.3
100	Province	0.124	0.855	-	0.937	+37.0, -27.0
		-7.150	0.894	2.355	0.962	+28.1, -22.0
	Eastern	1.046	0.454	-	0.733	+19.5, -16.3
	Central	-0.001	0.923	-	0.991	+18.4, -15.5
		-13.873	0.993	4.456	0.999	+ 7.0, - 6.5
	Southern	0.162	0.893	-	0.957	+28.6, -22.2
	Northwestern	-0.447	1.023	-	0.968	+25.3, -20.2
	Saint John main stem	-0.311	0.943	-	0.998	+ 4.6, - 4.4

TABLE II-1 (continued)

REGIONAL QP/QD REGRESSION EQUATIONS

$$\log_{10}QP/QD = e + f \log_{10}DA + g \log_{10}SNOW + h \log_{10}\%LS$$

Region	e	f	g	h	Multiple r-square	Standard Error (%)
Province	0.303	- 0.082	-	-	0.519	+14.7, -12.8
Eastern	0.170	-0.037	-	-	0.326	+ 5.4, - 5.1
	0.466	-0.032	-0.138	-	0.594	+ 4.4, - 4.2
Central	0.288	-0.074	-	-	0.906	+ 5.7, - 5.4
Southern	0.326	-0.073	-	-	0.167	+24.1, -19.4
	0.291	-0.045	-	-0.091	0.519	+18.9, -15.9
Northwestern	0.291	-0.082	-	-	0.596	+13.0, -11.5
Saint John main stem	-- No equation -- use QP/QD = 1.06 --					

Note: If the regression equations generate a QP/QD less than unity, which is possible for very large basins, a QP/QD ratio of 1.0 should be used.
The QP/QD equations for the Eastern and Southern regions are not statistically significant, but were nonetheless included because the Province-wide equation was biased for these regions. A comparison between actual QP/QDs for the Eastern region and predicted QP/QDs from the Province-wide equation shows that the Province-wide equation almost always predicts too large a QP/QD ratio. Similarly, for the Southern region west of the Saint John River, the QP/QD is overpredicted by the Province-wide equation, while it is almost always underpredicted for the Southern region east of the Saint John River.

TABLE II-2

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
01AF002 SAINT JOHN RIVER AT GRAND FALLS

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	3345.648	1165.491	0.348	0.283	2.715
LN X SERIES	8.050	0.381	0.047	-0.669	3.874

X(MIN)= 915.000
X(MAX)= 6250.000
LOWER OUTLIER LIMIT OF X= 1079.819

TOTAL SAMPLE SIZE= 54
NO. OF LOW OUTLIERS= 1
NO. OF ZERO FLOWS= 0

AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	3391.510	1126.380	0.332	0.394	2.630
LN X SERIES	8.073	0.344	0.043	-0.222	2.449
LN(X-A) SERIES	8.376	0.253	0.030	-0.062	2.387

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

PARAMETERS OF THE 3LN WHICH DUPLICATES THE CONDITIONAL FUNCTION:
A= -1088.667 M= 8.369 S= 0.257

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	1040.00
1.050	0.952	1720.00
1.250	0.800	2390.00
2.000	0.500	3220.00
5.000	0.200	4270.00
10.000	0.100	4910.00
20.000	0.050	5490.00
50.000	0.020	6220.00
100.000	0.010	6760.00
200.000	0.005	7270.00
500.000	0.002	7950.00

MAXIMUM DAILY DISCHARGE

TABLE II-3

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
01AD004 SAINT JOHN RIVER AT EDMUNSTON

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	3038.333	585.737	0.193	0.891	3.615
LN X SERIES	8.003	0.184	0.023	0.674	3.355
LN(X-A) SERIES	6.815	0.561	0.082	-0.066	4.058

X(MIN)= 2290.000
X(MAX)= 4200.000
LOWER OUTLIER LIMIT OF X= 2020.583

TOTAL SAMPLE SIZE= 12
NO. OF LOW OUTLIERS= 0
NO. OF ZERO FLOWS= 0

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

3LN PARAMETERS: A= 1988.952 M= 6.815 S= 0.561

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	2180.00
1.050	0.952	2350.00
1.250	0.800	2560.00
2.000	0.500	2900.00
5.000	0.200	3450.00
10.000	0.100	3860.00
20.000	0.050	4280.00
50.000	0.020	4880.00
100.000	0.010	5350.00
200.000	0.005	5860.00
500.000	0.002	6570.00

TABLE II-4

FREQUENCY ANALYSIS - THREE-PARAMETER LOGNORMAL DISTRIBUTION
01AD002 SAINT JOHN RIVER AT FORT KENT

SAMPLE STATISTICS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	2364.183	739.632	0.313	0.293	2.852
LN X SERIES	7.716	0.338	0.044	-0.699	4.350

X(MIN)= 691.000
X(MAX)= 4130.000
LOWER OUTLIER LIMIT OF X= 861.025

TOTAL SAMPLE SIZE= 60
NO. OF LOW OUTLIERS= 1
NO. OF ZERO FLOWS= 0

AFTER REMOVAL OF ZEROES AND/OR LOW OUTLIERS

	MEAN	S.D.	C.V.	C.S.	C.K.
X SERIES	2392.542	712.322	0.298	0.441	2.710
LN X SERIES	7.736	0.303	0.039	-0.142	2.494
LN(X-A) SERIES	7.900	0.257	0.032	-0.054	2.470

SOLUTION OBTAINED VIA MAXIMUM LIKELIHOOD

PARAMETERS OF THE 3LN WHICH DUPLICATES THE CONDITIONAL FUNCTION:
A= -394.157 M= 7.894 S= 0.260

FLOOD FREQUENCY REGIME

RETURN PERIOD	EXCEEDANCE PROBABILITY	FLOOD
1.003	0.997	917.00
1.050	0.952	1340.00
1.250	0.800	1760.00
2.000	0.500	2290.00
5.000	0.200	2940.00
10.000	0.100	3350.00
20.000	0.050	3720.00
50.000	0.020	4180.00
100.000	0.010	4520.00
200.000	0.005	4850.00
500.000	0.002	5280.00

MAXIMUM DAILY DISCHARGE

TABLE II-5

St. John River Flood Study

Summary of Flood Flows

Study Area	Drainage Area (km^2)	Flood Flow, m^3/s									
		Single Station Analysis (Maximum Daily Flows)						Regional Frequency Analysis			
		Q20	(1)	(2)	Q100	(1)	(3)	Q20	Q20*PF	Q100	Q100*PF
		CFA	Prorating by Drainage Area		CFA	Prorating by Drainage Area					
Grand Falls (WSC Station 01AF002)	21900	5490	5490	5490	6760	6760	6760	5281	5598	6054	6417
St. Leonard	21620		5427	5420		6678	6674	5220	5534	5981	6340
Siegas:											
d/s of Siegas River	21230		5338	5322		6564	6553	5135	5444	5879	6232
u/s of Siegas River	21130		5315	5297		6536	6522	5114	5421	5853	6204
St. Anne De Madawaska	21070		5302	5282		6518	6504	5101	5407	5837	6188
Green River	19520		4949	4893		6065	6025	4761	5047	5432	5757
St. Basile	19470		4937	4881		6050	6010	4750	5035	5418	5744
Edmunston (WSC Station 01AD004):											
d/s of Madawaska River	18890	4260	4805	4735	5350	5880	5831	4623	4900	5266	5582
u/s of Madawaska River	15500		4020	3886		4879	4784	3868	4100	4370	4632
Baker Brook:											
d/s of Baker Brook	15250		3962	3823		4805	4707	3812	4040	4304	4562
u/s of Baker Brook	14800		3857	3710		4671	4568	3710	3933	4184	4435
Fort Kent (WSC Station 01AD002)	14700	3720	3833	3685	4520	4642	4538	3688	3909	4157	4406

(1) Pro-rated by $(A1/A2)^{1.0}$
(2) Pro-rated by $(A1/A2)^{0.901}$
(3) Pro-rated by $(A1/A2)^{0.943}$

APPENDIX III

PERCEPTION METHOD

APPENDIX III

PERCEPTION METHOD

III.1 INTRODUCTION

Many significant flooding events that have occurred in this region are associated with ice jams or heavy rainfall during the spring freshet. It is quite possible, therefore, that an ice-related or rainfall plus snowmelt condition may produce a higher flood elevation for areas particularly sensitive to these conditions.

The Perception Method (Gerard and Karpuk, 1979) is a means of assigning a return period to a significant event that occurred either on a non-gauged system or, for certain hydraulic reasons, produced more severe flood conditions at one location than at the gauging station (i.e. an ice-related event may cause extensive flooding at a site where channel capacity is limited while the peak flow at the gauge may not have been unusually high). This additional information can then be used to estimate the probability distributions of floods for ice-breaking periods or to augment existing historical information.

In order to conduct such an investigation, a comprehensive field survey was undertaken to collect information on historical flooding. A number of area residents were questioned, archival information researched, photographs interpreted and high water marks (i.e. ice scars) surveyed in order to compile the most complete data base possible. Information collected is summarized in Appendix I.

In all cases, effort was made to tie-in the historical flooding information to geodetic datums by either surveying the elevation or making a reasonable approximation based on topographic information.

III.2 APPLICATION OF PERCEPTION METHOD

Data for each community was plotted on a separate Summary Diagram (See Figures III-1 to III-7 for examples). The purpose of each figure is to illustrate the relationship of the peaks to facilitate the ranking procedure and to formulate the record length for each peak by "filling-in" the x-axis to represent the period for which the observer may be identified with the observation. All elevations associated with a particular community, either surveyed or estimated, were ranked together without adjustment to account for the difference in horizontal location (i.e. one being several kilometres upstream from another). This assumption is supported by the fact that the HEC-2 model (and available mapping) indicates that the

average channel slope for the entire study reach is 0.0003 m/m or 0.03% which translates to a change in channel invert elevation of only about 0.1 m in 3 km.

As an example the record length associated with the peak event of 1979 in Saint Leonard was determined as follows:

- Area resident J. Hughs recalled events as far back as 1939 but did not recall one as severe, either ice-related or otherwise, as the event of 1979 (or at least could not provide enough information to permit assigning an elevation to any of his observations). In addition, Water Survey of Canada Gauging Station 01AF002 has been actively recording since 1931 and the peak flow for 1979 is the extreme flow recorded for this period. The resulting number of years of record associated with this event from these two sources is from 1931-1991 or 60 years.

- In addition, it was reported that, back in 1885, the river rose 16 ft at Van Buren. It was assumed that this meant 16 ft above normal water level and normal water level was assumed to be about 131.5 m. The number of years of record associated with this observation was assumed to be only one as records for years immediately prior or subsequent to 1885 were not available.

- Therefore, the total number of years of record for the observation of 1979 is 60 + 1 or 61 years.

The probability of being greater than or equal to, based on the following plotter position formation, is determined as follows:

$$P = \frac{m - 3/8}{N + 1/4}$$

where m is the rank, and

N is the number of years record

Substituting values for m(1) and N(61) makes P = 0.011 or 1.1%. The Return Period (T) for such an event may be determined by the relationship

$$T = \frac{1}{P}$$ (T for 1979 event is 90 years).

The results of the probability analysis (Perception Method) are summarized in Table III-1, together with the range of computed 100 year open water flood elevations for the same reach.

TABLE III-1

Saint John River Flood Study

Summary of Computed and Historical Flood Elevations

Study Area	HEC2 Section Number(s)	100 Year Computed (HEC2) Flood Elevations (m)	Highest Historical Flood Elevation (m)	Estimated Probability of Occurence for Historical Event (1)
St. Leonard + Van Buren	20-27	138.3-138.9	136.7	0.011
Grand River	28-29	139.4-139.5	137.2	0.045
St. Anne De Madawaska + Quisibis	33-35	140.1-140.5	139.0	0.013
Green River	41	142.1	140.7	0.032
Edmunston	45-53	143.5-145.1	141.9	0.032
St. Hilaire	58-60	149.3-149.6	147.3	0.250
Baker Brook	67-70	151.7-152.1	151.8	0.027
Claire\ Fort kent	76-87	158.2-160.3	157.9	0.013

SAINT LEONARD / VAN BUREN

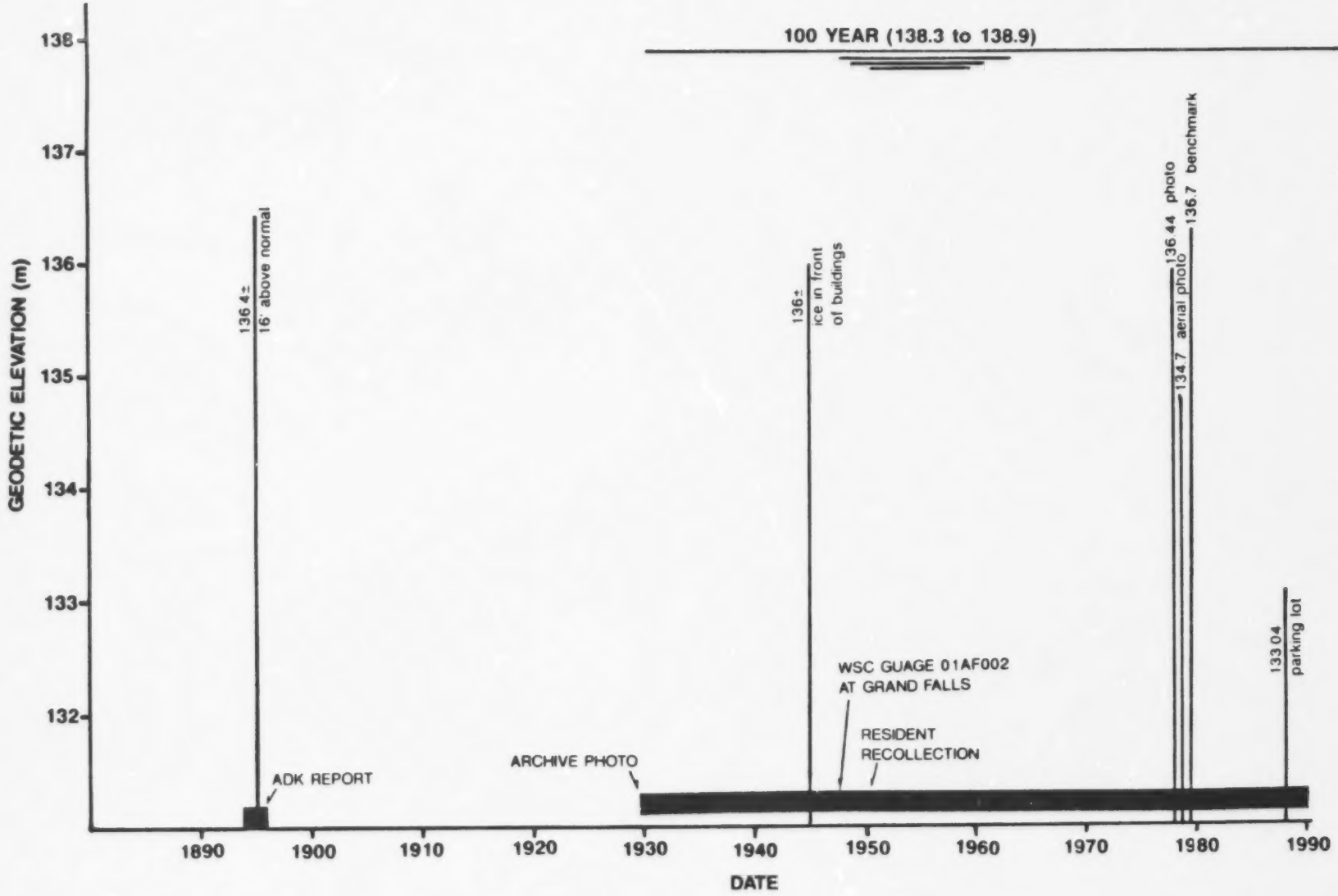


FIGURE III-1

SAINT-ANNE & QUISIBIS

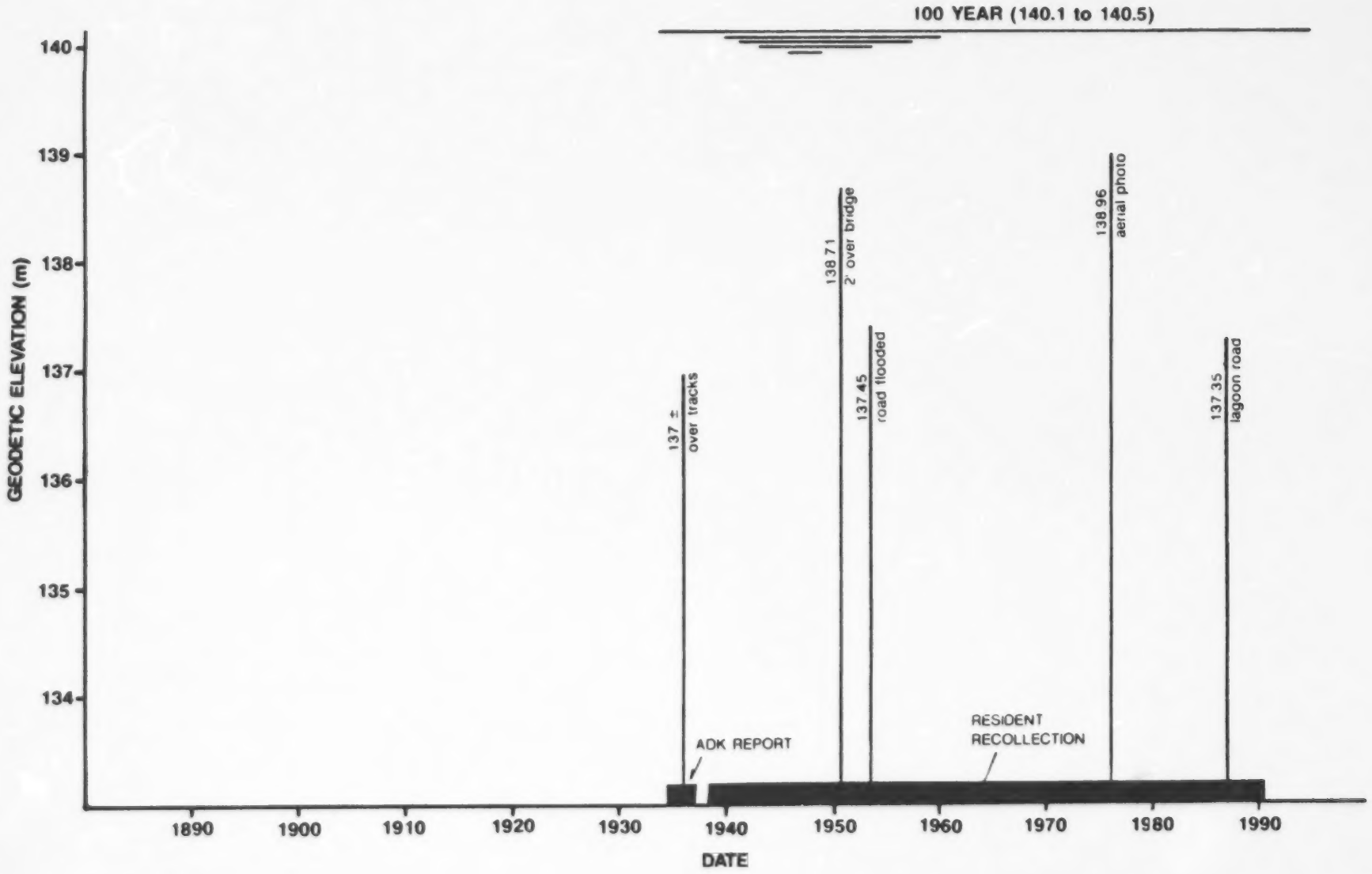


FIGURE III-2

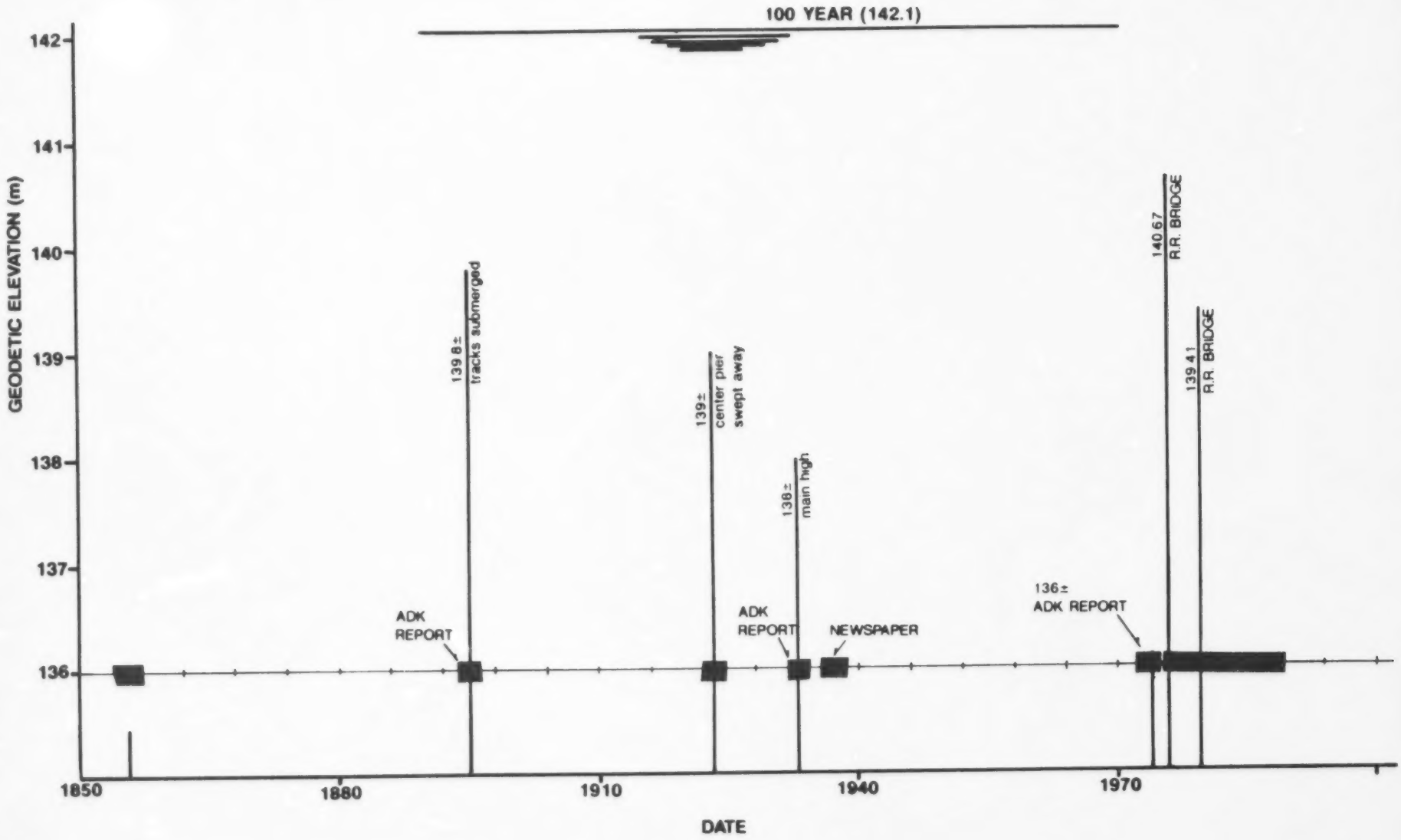

GREEN RIVER
100 YEAR (142.1)
142
141
140
139
138
137
136
GEODETIC ELEVATION (m)
139 8± tracks submerged
139± center pier swept away
138± main high
140 67 R.R. BRIDGE
139 41 R.R. BRIDGE
ADK REPORT
ADK REPORT
NEWSPAPER
136± ADK REPORT
1850
1880
1910
1940
1970
DATE

FIGURE III-3

EDMUNDSTON

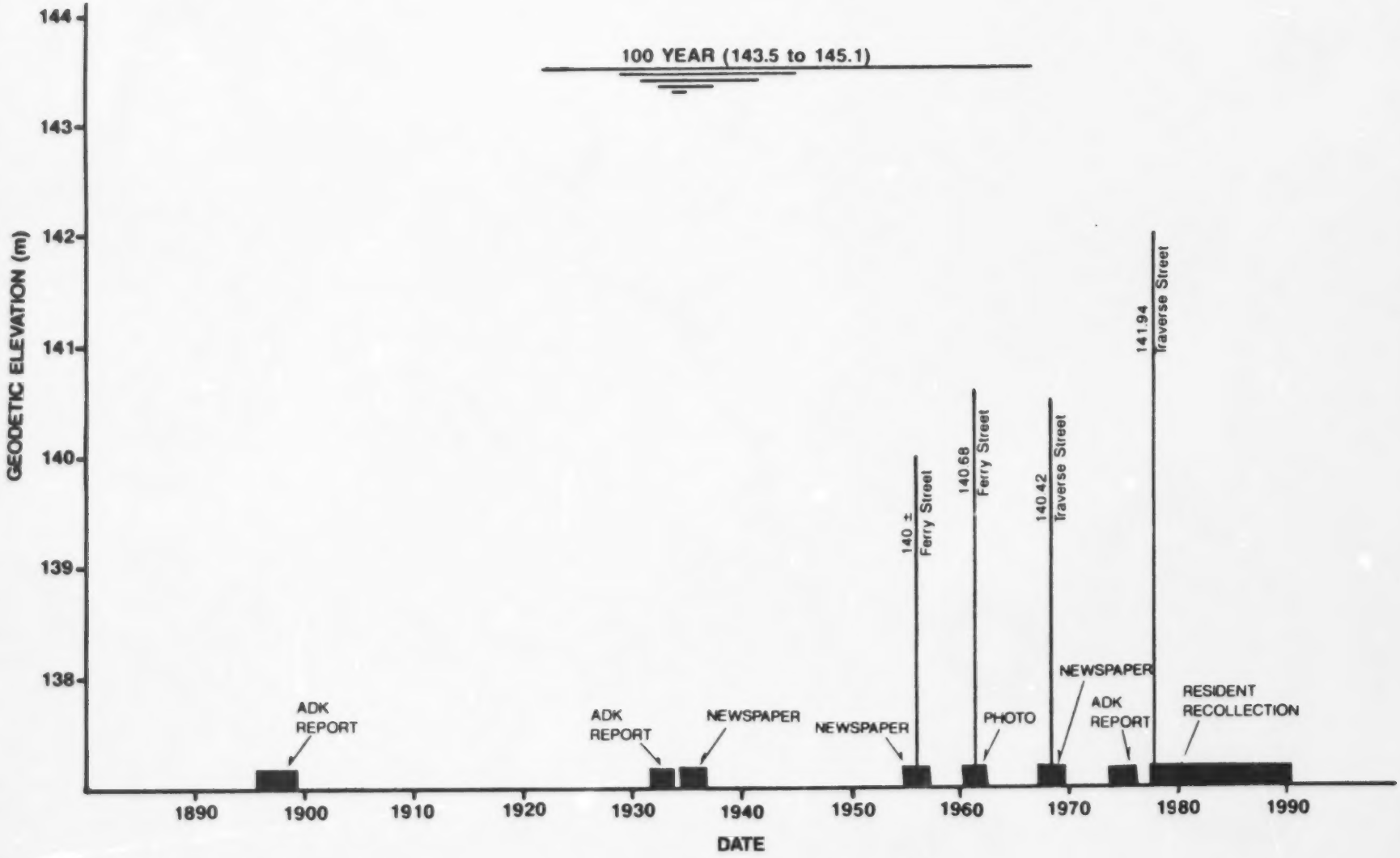


FIGURE III-4

SAINT-HILAIRE
100 YEAR (149.3 to 149.6)
GEODETIC ELEVATION (m)
149
148
147
146
145
144
143
147.28
ice scar
146.25
high water mark
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
DATE

FIGURE III-5

BAKER BROOK

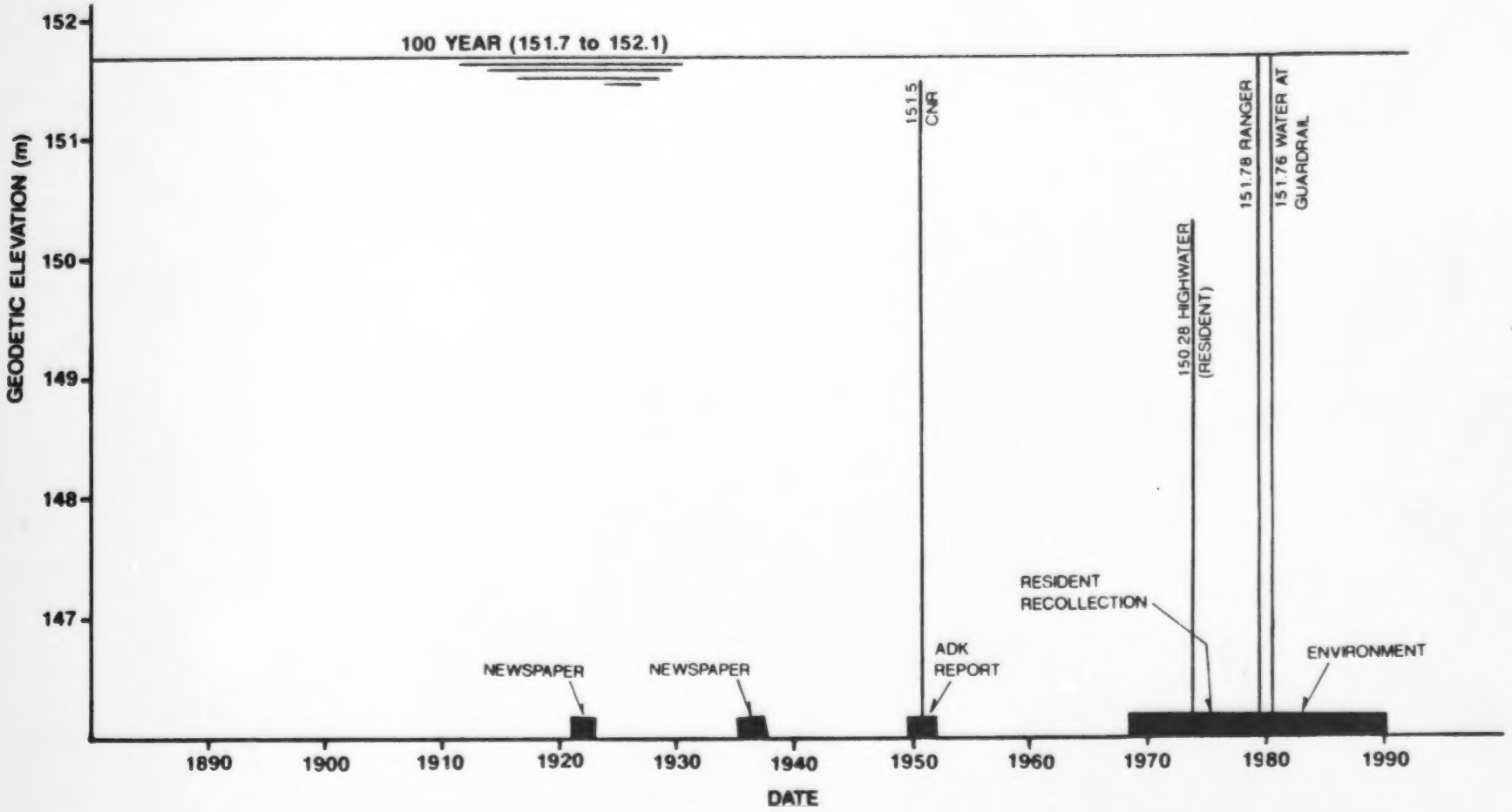


FIGURE III-6

CLAIR / FORT KENT

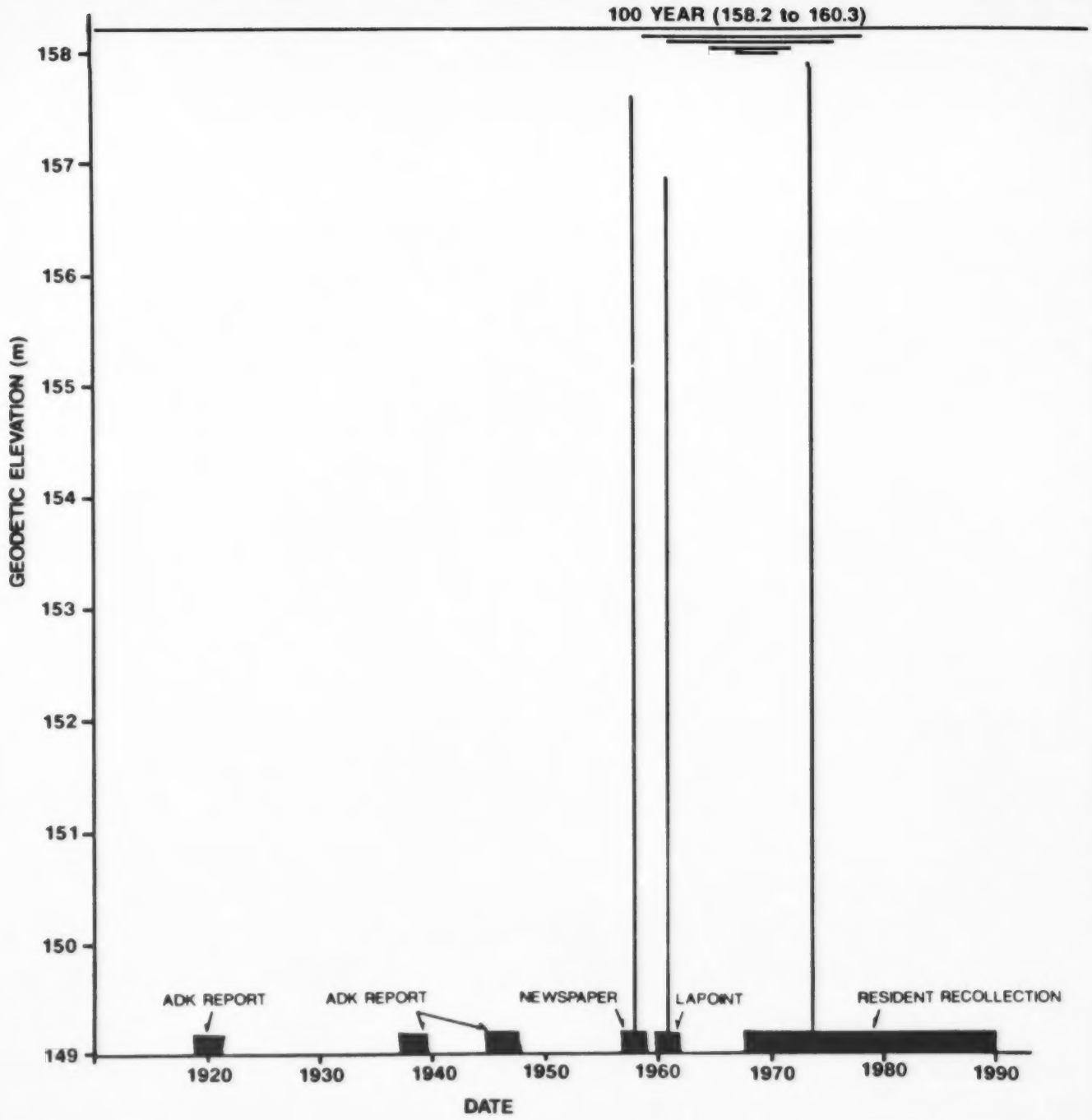


FIGURE III-7